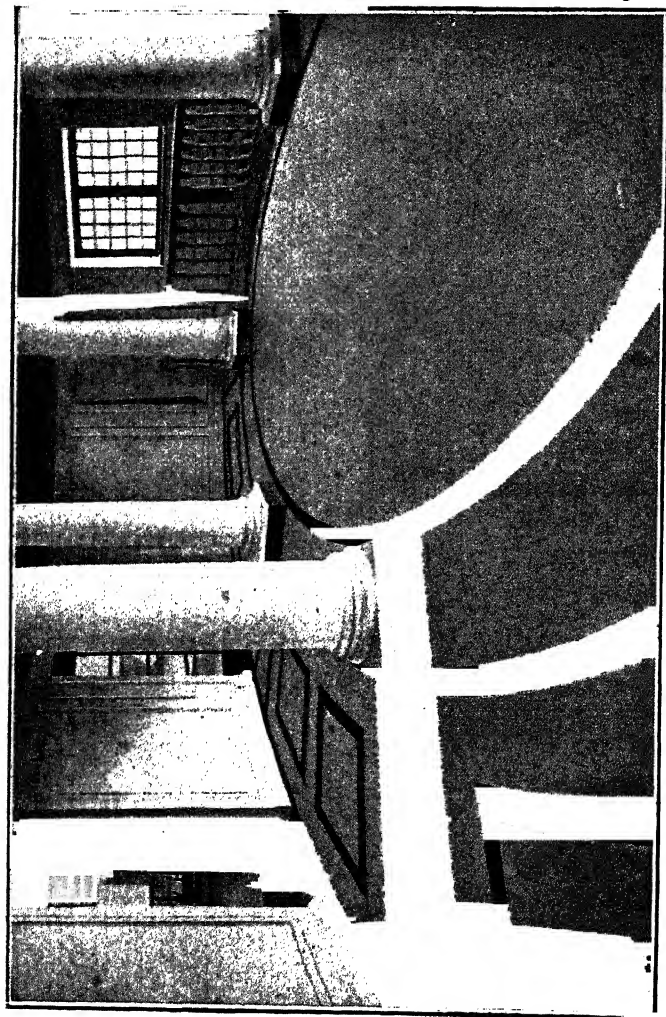


Frontispiece]



[Photo : British Doloment Co., Ltd.

An Effective Inset Design.

COMPOSITION FLOORING AND FLOORLAYING

BY

A. W. COMBER, F.I.C., Assoc.Inst.M.M.

With Frontispiece and 16 other Illustrations



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FOREWORD

THE Author of this volume has had an exceptionally wide experience in all aspects of the Magnesite Industry. He has conducted extensive research on Magnesite and associated technical problems in India, on the Continent and in this country. As a member of a committee under the auspices of the Department of Scientific and Industrial Research, he has assisted in formulating specifications in connection with the use of cementitious magnesite in this country. His work in this and other directions should lead to marked advance in practice and wider recognition of the many possibilities open to Magnesite Flooring.

Whilst the utility and attractiveness of these floors have a distinct appeal, there are certain principles essential to the actual art of successful laying which have not hitherto been thoroughly understood by its practitioners. Under prevailing conditions, operations are largely dependent upon "rule of thumb," and in "chancing it" variation in result may follow. In the following pages the Author definitely shows the art of laying a floor to be dependent on chemical reaction and well within the possibility of scientific control. Therefore, as in all industry, the degree of success reached is deter-

mined by the extent of the linking of science with practice. The effective link given by the Author will guide the empirical floorlayer into definite channels of work, thereby eliminating chance.

Apart from the practical floorlayer, this book possesses exceptionally high value and utility to Builder, Designer, Surveyor and Architect.

PERCY LONGMUIR.

P R E F A C E

COMPOSITION or jointless flooring is commonly understood to be a floor covering which is laid in plastic form and contains calcined magnesite and magnesium chloride as its chief components. Magnesium oxychloride results from the interaction of these substances and provides a binding agent for the aggregate which is embodied. There are other flooring materials, such as Portland cement and asphalt, to which the description, in a wider sense, might apply, but they do not properly form part of the present subject and will not be directly considered here.

This book is the first of its kind and has been written with the intention of enabling the floorlayer to realise, more fully than has hitherto been possible, the principles which are the foundation of his craft. It should furnish practical information which has not, so far, been readily available, and which, it is hoped, will be of real value.

The purpose of the book, however, goes beyond this. It should also serve to give the architect or the builder a more useful knowledge of the characteristics of the material in question, and perhaps a better appreciation that magnesite floorlaying is a highly technical operation and that co-operation

in providing suitable conditions for the work is an essential factor in ensuring successful results.

With regard to the terminology used in the following pages—so far as possible scientific expressions are avoided, but where they do appear their significance should be readily understood; the retention of *magnesite* instead of the more correct *magnesia* is justified in the text; *composition*, *jointless* and *magnesite*, when descriptive of flooring, have the same meaning. (A possible criticism of a minor sort may be met in advance, by quoting the O.E.D. as authority for the divergent plural forms, *dados* and *stuccoes*.)

The writer wishes to make acknowledgment to the Dow Chemical Company, of Midland, U.S.A., for permission to quote from the results of their valuable research work and for kindness in sending microphotographs for use in the book; to Mr. B. Bakewell, M.A., and Mr. H. M. Llewellyn, B.Sc., A.I.C., of the Building Research Station, who have read the manuscript; and to those who have kindly lent blocks or photographs. Special tribute should be given to Mr. A. E. Gentry, whose wide experience as a practical floorlayer has been at the disposal of the writer, to the extent of virtual collaboration in that part of the book which deals with the preparation and application of the oxychloride mix.

A. W. C.

226, Bishopsgate,
London, E.C.2.
April, 1936.

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CHAPTER I

INTRODUCTORY AND HISTORICAL

MAGNESITE is the mineral form of carbonate of magnesium and is found in many parts of the world. Pure magnesium carbonate contains 47.8 parts by weight of magnesium oxide and 52.2 parts of carbon dioxide. When the mineral is calcined, the latter constituent is evolved as a gas. Two varieties of magnesite, crystalline and amorphous or compact, are of considerable industrial importance.

Deadburned magnesite is the product of calcination at a high temperature, which may vary between 1450° and 1700° Centigrade, according to the type of mineral employed. It forms an excellent refractory agent, especially for the basic steel process. Crystalline magnesite, which is often associated with a proportion of carbonate of iron and is then known as *breunnerite*, is the usual raw material for deadburning. Refractory magnesite has no cementitious value.

Lightly calcined or caustic magnesite is nearly always prepared from the compact form of the mineral, by calcination at a temperature of about 850° C. The product is lighter and softer than deadburned magnesite and when mixed with mag-

nesium chloride solution, it sets to a hard mass, which is known as Sorel cement and is the basis of the modern composition flooring industry.

It should be noted that after calcination, the product has become an oxide and should properly be called *magnesia*. Universal custom, however, has



FIG. 1.—Quarrying Magnesite in India. [Photo: Author.]

warranted the use of the terms *deadburned* and *lightly calcined* or *caustic magnesite* for the commercial materials. Although academically incorrect, the practice is maintained here for convenience and the unqualified description *magnesite*, if conformable with its context, may be understood to refer to the lightly calcined product.

The first record of the use of calcined magnesite for structural purposes dates back to 1825, when Dr. Macleod experimented with it in a plaster on the counterscarp at Fort St. George, Madras. Comparative tests were made with (a) a mixture of two volumes of magnesite and one of sand, (b) a cement of lime and powdered ironstone and (c) ordinary lime plaster. An official report in the following year stated that after exposure to a heavy monsoon season, the magnesite cement was the hardest and best of the three. Dr. Macleod's material was gauged with water.

Other experiments were made by officers of the Madras Engineers and various claims were made on behalf of the new cement. One in particular, that the water-mixed material was hydraulic, obviously was none too well founded. Subsequently, Dr. Macleod was awarded an honorarium for his enterprise, but no commercial development directly followed.

In 1867, Sorel announced his discovery of the reaction between magnesia and magnesium chloride, with the formation of magnesium oxychloride and, twenty years later, the process was in commercial use in Austria, where the extensive magnesite deposits of Styria had recently been discovered. The date of the first oxychloride floor is uncertain, but the earliest application of the material for external stucco appears to have been at Trieste in 1889. Magnesite floors were being laid in Austria and Germany some years before they were intro-

duced into England, in the last decade of the nineteenth century. They were first seen in the United States as an exhibit in the Austrian pavilion at the World's Fair, Chicago, in 1893.

During the war, the supplies of magnesite to this country were controlled, chiefly for metallurgical needs, but composition floors were used in many of the buildings erected for the army. It was stated that magnesite cement was employed for the foundations of the long-range guns used by the German army for the bombardment of Paris.

In the post-war years there was a rapid increase in the amount of magnesite used in the United States, particularly for stuccoes and plasters. The peak year was 1929, when the world production of crude magnesite was over one million tons. At that time, the consumption of magnesite in America for wall-coverings was estimated to be three times that used for flooring. There has been very little exterior stucco-work done in this country and internal plastering has been largely restricted to low dados. Perhaps the possibilities in this direction have not been as fully realised as they should have been.

We are far from finality in understanding all the complexities of the oxychloride reaction and the effect on it of variation in the conditions under which it may take place, but there has hitherto been very little technological research directed in the interests of the British floorlayer. Notwithstanding this, there are firms in existence who can exhibit

floors which have been laid for over thirty years and are still giving satisfactory service. It is a matter of concern, however, that operations, as a whole, continue to be on an empirical basis.

The magnesite floorlayer has, perhaps, never realised that when laying a floor, he is employing a chemical process and he should be as precise in his methods as any other chemical manufacturer, to ensure consistently good results. There will be an endeavour, in the following chapters, to examine his problems and to indicate how this desirable precision should be attained.

CHAPTER II

CALCINED MAGNESITE

Most of the calcined magnesite used for flooring purposes in this country comes from Greece and India. Of late years some small supplies have been coming from Yugoslavia where extensive deposits of high-grade magnesite have been found and are now being developed on a commercial scale. Raw magnesite is usually calcined at the mines in shaft kilns, fired by producer gas, and the carbon dioxide is not conserved.

On account of this loss of carbon dioxide, it is not desirable to calcine at any great distance from the source of the mineral, as transport costs would have to be met on 50 per cent. of material which eventually is wasted.

If, however, facilities were available to conserve the gas for subsequent marketing, after conversion to the liquid or solid form, then calcination of imported mineral in this country would be a practicable proposition. As the best method for this purpose permits of closer thermal control than is possible with shaft kilns, calcined magnesite of

more regular quality and of known age could be supplied to the consumer.

Calcined magnesite is the most important component of oxychloride cement and the floorlayer's success depends to a large extent on the maintenance of a consistent standard in the chemical composition and physical characteristics of the material which he receives.

Chemical Composition.—The chief impurities in calcined magnesite are silica and lime. The former is not of special importance, as its presence has no adverse effect on the setting reaction or on the subsequent behaviour of a floor. In excessive amount, it acts as a diluting agent and proportionately reduces the content of active magnesia in the material. The percentage of silica in the usual commercial product is, however, rarely high enough to have an appreciable effect and, ordinarily, need not be taken into account.

Lime may exist in calcined magnesite either in an active or an inert state. There is no need here to discuss the chemical differences involved, but the presence of more than several units per cent. of active lime may be decidedly harmful. If the proportion of total lime is as much as 4 per cent., there will be a risk in using the magnesite and a maximum of 3 per cent. should be considered the permissible limit.

In addition to silica and lime, there is usually a small proportion of oxide of iron. In calcined

magnesite prepared from the compact form of the mineral, this is generally very low but, in increasing proportion, it causes slight discoloration of the material, which is normally quite white. As composition floors usually have a pigment embodied, this is not a serious objection. Occasionally, magnesite of Continental origin is offered, which is almost buff-coloured. This has been calcined from a crystalline mineral containing ferrous carbonate. Except for white or light-coloured floors, the tint itself is no special disadvantage, but occasionally the amount of oxide of iron may be high enough to have some effect in replacement of magnesia, as may happen with excessive silica, and the material may be correspondingly less valuable. This type of magnesite should always be tested also for lime.

The foregoing, with magnesia, represent the normal solid constituents of commercial magnesite. In addition, there is always a variable percentage of water and carbon dioxide, often classed together in an analysis as "Loss on ignition." Usually, the calcined material as it leaves the kilns contains 1 or 2 per cent. of residual carbon dioxide. If calcination is carried far enough to expel the carbon dioxide completely, there is a risk of a proportion of the product becoming overburned and in a large measure unsuitable for its special purpose. Later, in the operation of grinding and during storage, moisture and, to a less degree, carbon dioxide are absorbed from the air. Prolonged storage, espec-

ially under unsuitable conditions, will cause the magnesite to become lumpy, or, when in bags, to cake on the outside, owing to hydration. Commercial magnesite should, at the time of use, show a loss on ignition not exceeding 7 or 8 per cent. A figure appreciably in excess of this, probably indicates staleness and the material should be rejected.

The chemical analysis of a sample of magnesite gives three positive indications of quality:—

(1) Lime.

(2) Water and carbon dioxide.

(3) Magnesia, which apart from the presence of (1) and (2) may also vary in amount according to the proportion of silica and oxide of iron.

Nos. (1) and (2) may in themselves be sufficient to condemn a sample but commercial magnesite is usually satisfactory in this respect.

The proportion of magnesia in calcined magnesite should not be less than about 88 per cent., although a small tolerance of 2 or 3 per cent. is sometimes allowed.

It may be mentioned in passing, that this magnesia may have some variation in its characteristics, which are not shown in a chemical analysis. These may be either chemical or physical, but full consideration to the problems involved cannot conveniently be given here. This variation is, to some extent, due to the mineralogical nature of the raw material but may also be caused by lack

~~INSPECTION~~

of uniformity in the thermal conditions of the calcination process.

Physical Nature.—The physical characteristics of calcined magnesite are considered in some detail in a later chapter, but their general importance may be noted here.

In practice, it is a fairly simple matter for the calciner to maintain a satisfactory standard of chemical composition for his magnesite, but this is not enough. Within the permissible limits, one sample may provide a better-looking analysis than another, but it is not necessarily the more effective material in use.

Analysis alone will not indicate what may be termed the degree of reactivity of the material with magnesium chloride solution, for physical condition is often the determining consideration. It has just been noted that the scope of this book will not permit a full scientific discussion of the factors which are operative in this connection, but it may be stated that the complete significance of them is not yet thoroughly understood.

This is not, in itself, a serious matter. If a certain grade of product is regularly maintained by the calciner, to be determined by analysis and certain physical tests, then, with standardised methods of application by the floorlayer, consistent results may be secured in practice. This obviously calls for more informed co-operation between calciner and consumer than has hitherto been the case.

It cannot be too strongly emphasised that uniformity is of essential importance. Commercial magnesites may frequently show considerable diversity under test. As a rule, the floorlayer does not concern himself about this and therefore does not adjust his methods accordingly. While this is not always the cause of bad failure, it does constitute an unrealised handicap and is frequently the explanation of many of the difficulties which arise. For example, raw magnesite may be calcined at a relatively low temperature, say 750°C. , with a high kiln time factor. Such a magnesite, although carrying more than the normal amount of residual carbon dioxide, if used soon after calcination, would set so rapidly as to be quite unserviceable. Unless the carbon dioxide and water are separately determined in the analysis and the high proportion of the former noted, it might be inferred from the loss on ignition alone that the material is stale and presumably slow setting.

Some commercial magnesites will take three or four times as long for the initial set as others presumably of the same standard, and this is not always due to hydration on account of prolonged storage. The result in such case is that the floorlayer is never sure, especially with new deliveries, when his floor will be ready for finishing off. This may happen in the middle of the night or, at its best, it often entails early or late attendance by the operatives, with increased expense. Every floorlayer knows that unless he can trowel or scrape

his floor just at the right time, the operation becomes much more laborious and, in some circumstances, it may be impossible to ensure a satisfactory job. Within reasonable limits, the exact time is not important as long as the setting period remains a tolerably consistent figure, but the floorlayer must be in a position to know approximately how his magnesite can be expected to behave. He can then make his arrangements accordingly.

The formulation of a close specification, apart from chemical composition, for a calcined magnesite, is a matter of some difficulty, particularly as the inter-relation of such properties as setting time, expansion and contraction during and after the setting reaction, volume weight, ultimate mechanical strength, etc., has not been precisely determined. If a detailed specification included the most desirable standards for all these qualities, then the calciner would not, under present conditions, be able to meet it.

The best way out of this difficulty is to specify to the calciner the more important physical requirements, scheduled between reasonably wide limits, and then ask him for a standardised product, guaranteed between narrower limits, to be fixed by him. He has a margin within which to fix his own standard and then, by systematic thermal and mechanical control of his calcination process, he should be able to ensure to the consumer magnesite of consistently even quality.

CHAPTER III

SOREL'S DISCOVERY OF MAGNESIUM OXYCHLORIDE CEMENT

ON July 15, 1867, a paper was read before the French Academy of Sciences, on behalf of Stanislaus Sorel, announcing his discovery of the magnesium oxychloride reaction. This occasion marked the starting-point of the modern composition flooring industry, and it seems fitting that a translation of the original paper, which was published in *Comptes Rendus* for 1867, should be included here. The translation has intentionally been kept as literal as possible.

ON A NEW MAGNESIAN CEMENT

I have the honour to submit to the judgment of the Academy a new cement, based on the principle of the zinc oxychloride cement introduced by me in 1855. It is an oxychloride of magnesium, basic and hydrated.

The cement is made by gauging magnesia with a solution of magnesium chloride, more or less concentrated, and the stronger the solution, the harder the cement. In most cases, I use a solution of 20 to 30 degrees by Baumé's aerometer.

It is possible with the new cement, wholly or in part, to replace the magnesium chloride by certain other chlorides or salts, having as their bases, metals of the three first sections of Thenard's classification.

This magnesian cement is the whitest and hardest of all cements and it can be moulded like plaster. By mixing with the cement other suitable materials, moulded objects can be made, which have the hardness and colour of marble. This cement will take all colours.

I use it to produce mosaics of very fine appearance, imitations of ivory, billiard balls, etc.

The industrial importance of the new product will be appreciated from the samples which I have the honour to submit to the Academy.

The new cement possesses in the highest degree an agglutinative property, which enables it to form solid masses at very low cost, by bonding large proportions of aggregate of little value. One part of magnesia can bond more than twenty parts of sand, limestone or other inert material, to form hard blocks, while lime and ordinary cements can only bond two or three times their weight of other substances.

On account of this aggregate, building is possible where the ordinary construction materials are not available. Thus, if not themselves obtainable on the site, it is only necessary to transport magnesia and magnesium chloride, as, with sand, shingle and other materials, more or less hard, found on the

spot or in the locality, excellent blocks resembling building stone can be moulded.

There is another application of the new cement which is very important and which already has had the advantage of nearly two years' trial. It is to use it for the hardening of walls of soft limestones and plasters. For this purpose, the cement is specially compounded and used in a very fluid state. It is applied with a brush, as if it were an ordinary stone-paint.

This magnesian cement, which is resistant to the action of water, can be prepared at very low cost, especially by using magnesia extracted from the mother-liquors of saltworks. This can be done by the ingenious process of M. Balard, which enables magnesia and hydrochloric acid to be obtained at the same time, by decomposing the mother-liquors, consisting in great part of magnesium chloride, by means of quicklime. A double decomposition results, which produces magnesia and chloride of calcium. I use mother-liquors of 20 degrees and I add less than an equivalent of lime for an equivalent of magnesium chloride, so that no lime remains undecomposed and some magnesium chloride is still in the liquor. I obtain by this method, in addition to magnesium hydrate, which it is necessary to calcine, calcium chloride containing a certain amount of magnesium chloride.

As this mixture of double chloride is in considerable quantity, I have sought to make use of it. I have found that by adding a little magnesia

and other materials in powder, such as chalk or limestone, an excellent stone-paint is formed, which is very adherent and has a hardening effect on the walls to which it is applied. The liquid can also be employed with magnesia to form a cement.

It can be seen, therefore, that by my process, value is given to materials which are otherwise valueless. Industry is offered a new raw material whose constituents are largely provided, not from the solid crust of the earth, but from the waters of the sea, which are inexhaustible. The raw material of the new cement will therefore never be lacking, for it does not come from quarries and mines, whose stores diminish each day and end inevitably with complete exhaustion.

The magnesia used by Sorel was not produced from the calcination of mineral magnesite but was prepared by chemical methods. Unlike the earlier experimenters in Madras, who used calcined magnesite mixed with water, he makes no claim for hydraulic properties in his cement. The essential feature of the discovery was the interaction of magnesia and magnesium chloride solution.

Sorel, who was an engineer rather than a chemist, evidently realised that his new product had very great possibilities for industrial application. It is often said that he was the first to suggest the use of sawdust as an especially suitable aggregate, but it will be seen that there is no such reference in his paper.

The account of the preparation of magnesia and magnesium chloride from the waste mother-liquors at saltworks is very interesting, but his vision of the basic materials of a new industry being provided for all time from the inexhaustible waters of the sea and not from the solid crust of the earth has failed to become a reality. The quarryman and the miner supply us to-day with our magnesite and magnesium chloride.

CHAPTER IV

THE OXYCHLORIDE REACTION

MAGNESIUM oxychloride provides the bonding agent in the various forms of magnesite cement compositions. It is often referred to as a chemical compound of definite constitution, but this is not strictly the case. Its composition has been determined within close limits but cannot yet be represented by an exact formula which is always applicable.

There appears to be an unstable association between its components, which is affected by changing conditions of environment, such as temperature and humidity. Research into the problem is a matter for pure science, but its results may be of direct technological significance. There is, for example, an hypothesis that a variable liquid phase, in the form of an interstitial solution of free magnesium chloride, always is present. The arguments for this are academic and, in part, mathematical, but the conclusions may help to explain the trouble known as "sweating."

Attempts have been made, from time to time, to evolve a balanced mix, on the basis of a theoretical formula for magnesium oxychloride, but, so

far, no special advantage appears to have been gained.

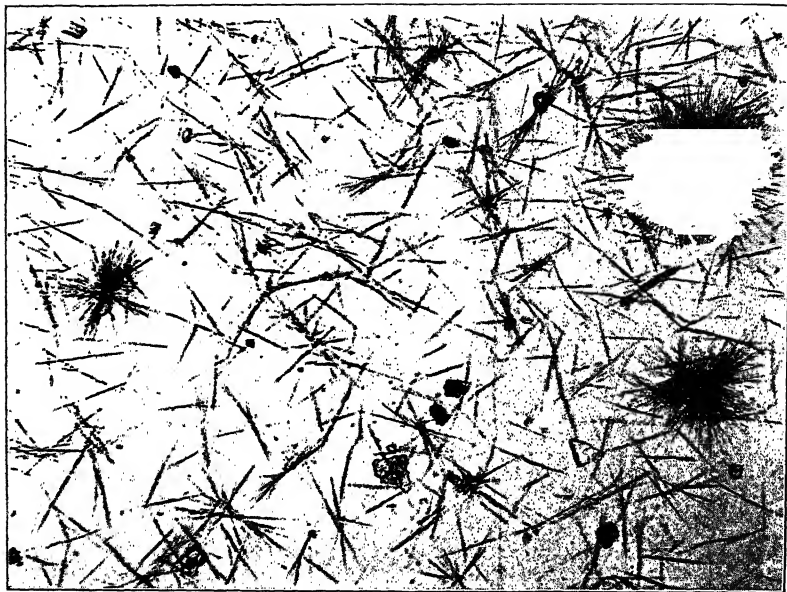
As Sorel demonstrated, magnesium oxychloride forms a hard mass, possessing in itself high mechanical strength but also capable of binding many times its own weight of inert aggregate. Without such admixture, the volume change of a mix of neat magnesite and magnesium chloride, continuing after the set, would be so great that the material would be useless for any practical application.

Reference to the unstable nature of magnesium oxychloride has been made, but such instability does not imply inherent weakness or lack of permanence in service. In a stucco, which is constantly exposed to changing weather conditions, there is slow but persistent leaching, due to atmospheric action, which gradually dissolves out the soluble chloride. At the same time, carbon dioxide from the air combines with the magnesia which is re-formed, converting it to magnesium carbonate and enabling the material to retain its hardness.

Similar action may operate with a floor, but to a far less extent. Periodic washing may take the place of atmospheric leaching, but the usual surface application of oil or wax prevents much penetration and consequent removal of chloride. In floors subject to sweating, there is, however, a loss on this account, although, in some cases, the trouble is due to an original excess of magnesium chloride. This will be discussed later. Where carbonation does occur with a floor, it is usually only a surface

alteration and the magnesium carbonate which is formed acts as a protective layer and prevents deeper action.

In an oxychloride mix, the particles of magnesite react with magnesium chloride and become elongated,

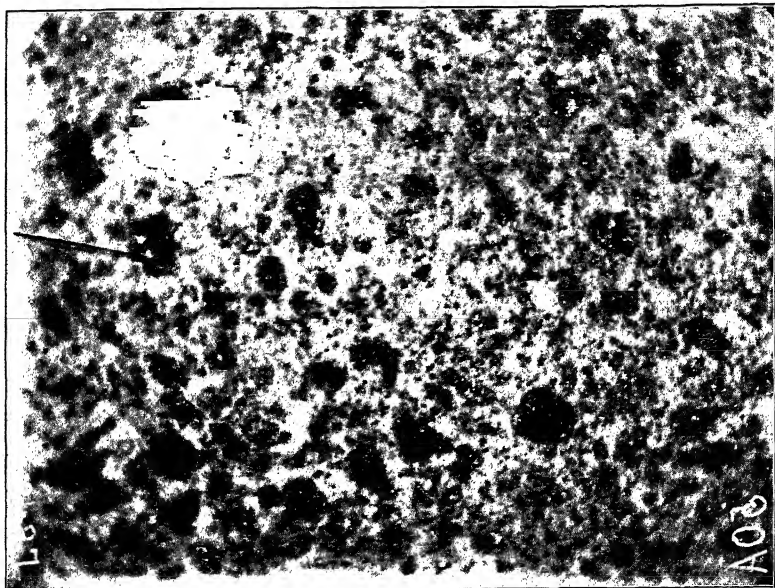


[Photo: The Dow Chemical Co.]
FIG. 2.—Calcined Magnesite After One Week in Magnesium Chloride Solution (22° Be). ($\times 100$)

(Note incomplete reaction with large particles.)

to form crystals of magnesium oxychloride, which have an interlaced appearance. Reaction, in the case of finely ground magnesite, is fairly complete at an early stage. There is always some change of volume, in the form of contraction or expansion, during the process. Sometimes one of these changes

follows the other and the two movements are mutually corrective. It is always desirable that the greater part of any action of this kind should take place while the material is still plastic, otherwise shrinkage cracks or buckling will occur.



[Photo: The Dow Chemical Co.]

FIG. 3.—Portland Cement After One Week in Water. ($\times 100$)

If there is an undue proportion of coarse particles, the cores of these are more slowly acted upon by the magnesium chloride and volume changes may continue to take place after the material is rigid, which, in the case of a floor, obviously leads to trouble.

Portland cement is not usually ground so finely

as calcined magnesite and the setting reaction is of a different type. As the particles hydrate they become surrounded by a colloidal mass which, on hardening, acts as the binding medium. The cores of Portland cement particles, except of the very finest, do not completely react and thus form the weakest part of the agglomeration.

This explains why magnesite cements develop much higher tensile and compressive strengths than Portland cement. This superiority is also due to the fact that the nature of the setting reaction permits finer aggregates to be used in magnesite cement mixes. The smaller particles of inert material require correspondingly thinner films of the binding agent and a more homogeneous result is obtained. The cost of magnesite prevents its extended use in massive form for structural purposes.

CHAPTER V

PHYSICAL CHARACTERISTICS OF CALCINED MAGNESITE

THERE are certain elementary properties of calcined magnesite, dependent upon its physical or mechanical condition, which can readily be tested.

Specific Gravity.—The specific gravity of compact magnesite mineral is about 2.94. When calcined, the product is apparently lighter, but actually has a higher specific gravity. This is because calcined magnesite, in lump form, is minutely porous, following the expulsion of carbon dioxide and resultant particle shrinkage. Well-calcined magnesite, which has not been kept for too long a time, should have a specific gravity of about 3.20. As a rule, overburned material has a higher and underburned material a lower figure. Magnesite which is stale and has hydrated will have a low specific gravity.

Volume Weight or Density.—This is the weight per gallon or per cubic foot or other convenient unit of volume, and although it might be expected to vary directly with the specific gravity, it does not necessarily do so.

The individual particle of calcined magnesite has a relatively high specific gravity, higher than the specified standard for Portland cement, but the material in bulk, even after grinding, has a characteristic lightness, which, for want of a better term, may be described as due to its texture. This bulkiness is of practical advantage to the floorlayer.

Volume weight is not directly related to specific gravity or to fineness of grinding and can be decreased by as much as 15 per cent. by shaking up the sample under test and so air-separating the particles.

It has been suggested that the volume weight of magnesite may depend, to some extent, on the method used for grinding it, the resultant shape of the particles determining the closeness of their association. There is at least a possibility that electrical charges are induced by the friction of grinding, causing mutual repulsion between individual particles.

Reference has so far been made to what is known as loose or poured density. The test is conducted by stirring the sample through a screen, so that it is discharged by means of a wide-stemmed funnel into a container of known capacity. The material is allowed to settle without any jarring of the container. The surface is struck off with a straight-edge and the nett weight of the measured quantity is ascertained. Unless the test is conducted under standardised conditions, variable results will be obtained. A fairly good calcined magnesite should

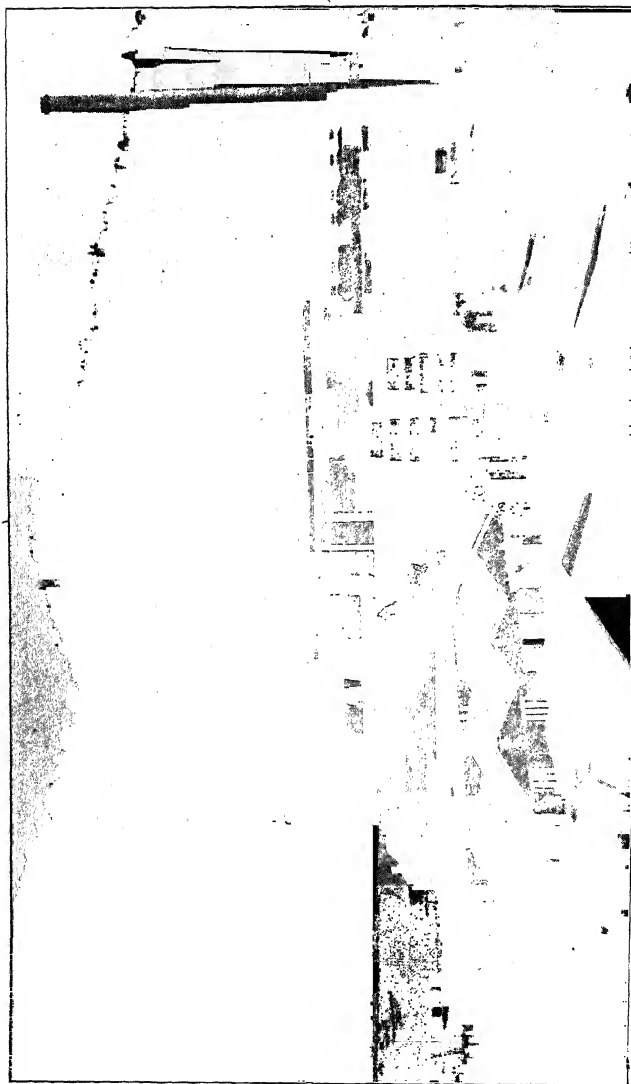
give a poured volume weight not exceeding 7.5 lb. per gallon or 47 lb. per cubic foot.

Packed or shaken density is determined by filling in the same manner, but the container is jarred, either by hand or mechanical means, to consolidate the material. When no further settlement takes place, the surface is struck off and the container and contents weighed. Shaken volume weight may be as much as 50 per cent. higher than the loose weight.

The large variations which are caused by the method of filling the container obviously show that the ordinary practice of proportioning by volume, when preparing flooring mixes under working conditions, is unsound. Mix components should always be weighed.

Fineness.—Before calcined magnesite can be used by the floorlayer, it must be ground. Both Grecian and Indian calcined magnesite are usually shipped either to British or nearer Continental ports, in lump form and ground as required.

Fineness is a property which can be definitely specified and should be such that at least 97 per cent. of the material passes a sieve of 100 meshes to the linear inch (British Standard Specification) which allows a maximum particle diameter of 0.006 inch. Preferably 75 per cent. should also pass a 200-mesh sieve. The sample for test must be shaken through the sieve either by hand or mechanical means and not brushed through.



[Photo: Anglo-Greek Magnesite Co., Ltd.]

FIG. 4.—Calcination Plant in Greece.

Although the maximum size of particle, of the ground material, can be specified, there is still field for research on the effect of particle shape. Edge-runner or millstone grinding causes the formation of rounded particles, while with mills of the disintegrator type the fragments are more angular. There is not yet enough evidence to determine whether there is special advantage in either form. Reference to the possible bearing of particle shape on volume weight has already been made.

The three physical properties discussed, specific gravity, volume weight and fineness, are qualities of calcined magnesite which are directly determinable on the material, without first causing it to take part in any chemical reaction.

There are other characteristics which are influenced, partly by the chemical composition of the magnesite but to a greater degree by the physical state which it acquires as a result of the thermal conditions of the calcination process. These can only be examined by testing the material under conditions which approximate, to a greater or less extent, to those occurring in actual practice. Magnesium oxychloride must be formed by admixture with magnesium chloride solution and also, for some test conditions, with proportions of standard aggregate material.

From the floorlayer's point of view, the chief of these secondary qualities are setting time and volume change or the degree of expansion or contraction which takes place as a result of the setting

reaction. Tests for these factors may be made on neat magnesite and are valuable as a means of comparison over a series of samples. Standard limits may be formulated, as the results obtained represent, in intensified form, what actually happens in practice, when aggregate is included.

Setting Time.—The initial set of a magnesite cement denotes the first stage of stiffening up, when the mixture loses its mortar-like consistency. Laying must be finished before this occurs. By the time of the final set, the material has become too hard to work. Surface trowelling must be done during the period between the initial and final setting, and obviously the later this is left, the more arduous the operation becomes.

A very quick setting magnesite is usually either too fresh from the kiln or has been calcined at too low a temperature. Apart from the probability of excessive volume change in the floor, this necessitates the handling of very small batches, which is economically undesirable.

Setting time tests are often done on neat magnesite, and an initial set in under 1 hour and a final set at about 3 hours would be a reasonable requirement. The addition of aggregate has a retarding effect and would therefore prolong the time of final set to an extent which would make it possible to lay overnight and, under normal conditions of temper

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So long as his material does not set unduly rapidly or is so slow that it is sluggish to work, the main object of knowing the normal setting period of the particular mix he is handling is to enable the floorlayer to make his arrangements to the best advantage.

Special apparatus is needed for the precise determination of setting time, but it is often possible to get a sufficiently approximate idea by making up test pats of the mix to be used and observing how they harden off.

Volume Change.—In some respects, the most important characteristic of a calcined magnesite, to the floorlayer, is the extent of the change of volume, in terms either of linear expansion or contraction, which takes place during the setting process and, in some cases, for an indefinite period afterwards.

If the greater part of any such change happens while the material is still plastic, little harm is done. An early and gradual contraction may be counteracted by a later expansion and a corrective process thus takes place, within the limits of the elasticity of the floor. If, however, one or other of these movements persists in the material after it is rigid, then expansion will eventually cause the floor to buckle and to leave its base and contraction will result in cracking.

Abnormal volume change is usually attributable to the magnesite and may arise from several causes, such as calcination at too low a temperature, a high

content of active lime and unsatisfactory grinding, with an undue proportion of coarse particles. The remedy is obviously in the hands of the calciner. Excessive contraction in the early stages may be caused if magnesium chloride solution is absorbed from the mix into a porous base or if conditions favour rapid evaporation of moisture from the wet material. Harmful change, in either direction, may result from badly balanced proportions in the mix.

A safe limit for volume changes on test bars of a standard flooring mix is a maximum expansion of 0.15 per cent. and a maximum contraction of 0.25 per cent. on the length, within 30 days of moulding. It should be noted that the change in a bar, which is free to move and is exposed to the air on all sides, is relatively greater than that which would take place in similar material bonded down to a floor and may amount to ten times as much.

Mechanical Strength.—As magnesite composition flooring is essentially a floor finish and not a structural factor in a building, the mechanical strength is not of primary importance, if the material is otherwise sound. Tensile and compressive strengths of magnesite cements are exceptionally high, but are naturally influenced by the type of aggregate used. A mix containing a large proportion of sawdust or wood flour would not be expected to give such good results as a balanced mix of magnesite and a mineral aggregate like silica. Magnesium oxychloride will show much greater mechanical

strength than Portland cement if tested under comparable conditions. It has been described as the strongest binding agent known.

Soundness.—There have been attempts made to bring to a common denominator all the factors which contribute to the suitability of a magnesite for flooring work and to evolve a simple test for what, failing a better term, is described as soundness.

One test, similar to that specified for Portland cement, requires the use of a Le Chatelier gauge and, in effect, measures the expansion under intensified conditions, such as prolonged immersion in boiling water. Another test, which is said to be indicative of excess lime, involves moulding the magnesite into a pat with tapering edges and exposing it to the action of steam for several hours. In this case, unsuitability is shown by cracking, disintegration or distortion. Some floorlayers fill a small bottle with the plastic mix of magnesite and magnesium chloride and if the bottle cracks, after the mass has set, the material is condemned.

No single test can yet be relied upon to give positive information on the general value of a magnesite. The calciner should supply to a specification which, apart from chemical composition, should comprise, at least, limits for coarseness, volume weight, setting time and volume change. If in these respects a constant standard is maintained, the floorlayer will probably have little cause for complaint. He can always have his material

tested if he has reason to suspect that its quality falls short of contract terms and therefore may be a cause of trouble.

The real evidence of a satisfactory standard is furnished by behaviour under working conditions, but this is not always a practicable method of trying a magnesite of unknown quality especially when preliminary examination will go a long way towards avoiding any risk of failure when in use.

CHAPTER VI

MAGNESIUM CHLORIDE

TOGETHER with magnesite, magnesium chloride is a necessary agent for the oxychloride reaction. Most of the needs for floorlaying purposes in the United Kingdom are met from Germany, although, of late years, a product of good quality from India has been on the market. Magnesium chlorides of French and Russian origin are occasionally offered.

German magnesium chloride is a by-product obtained during the preparation of potash compounds and other salts from the natural alkaline deposits at Stassfurt. The Indian material is similarly a by-product but from sea-water, which is evaporated in salt pans, by the sun's heat, primarily for the crystallisation of ordinary salt.

The magnesium chloride which is commonly in use is packed in iron drums holding $5\frac{1}{2}$ cwt. The material is run into the drums as a thick, hot syrup, which sets to a solid mass. Technically it is described as a hexahydrate, which means that each molecule of magnesium chloride is associated with 6 molecules of water. If such material were free from impurities, it would contain 46.9 per cent. true or anhydrous magnesium chloride and 53.1 per cent.

water. Flake magnesium chloride of similar composition is also obtainable. Other forms are manufactured to a small extent, such as the tetrahydrate, with 4 molecules of water and a theoretical composition of 57 per cent. true magnesium chloride and 43 per cent. water. It is impracticable to remove the water by evaporation and so prepare an anhydrous product, because, as the magnesium chloride becomes dehydrated by heat, it decomposes, magnesium and hydrochloric acid being formed.

Nearly every floorlayer uses the solid fused magnesium chloride, and although there is occasionally a slight variation in composition, this lies within narrow limits and, if obtained from a reputable source, an even standard of quality may be expected.

Unlike calcined magnesite, which, apart from specified limits for some of its impurities, must satisfy certain physical requirements, chemical analysis alone is sufficient to determine the suitability of magnesium chloride.

Good commercial material should contain about 98 per cent. of hydrated magnesium chloride. The usual impurities are calcium chloride, which, if present to the extent of more than 1 per cent., may cause volume change and subsequent weakness; sodium and potassium chlorides, which are contributory causes of efflorescence on a finished floor and should be below 2 per cent.; and magnesium sulphate which should not exceed 0.5 per cent.

Although the 5½-cwt. drum is a convenient size for regular use, it would be an advantage to the

floorlayer if he could purchase part of his needs in packages of one-half or one-quarter of this capacity. The material can only be unpacked by stripping away the drum, and as the solid magnesium chloride is deliquescent, rapidly absorbing water from the air, it must be put into the dissolving tank or into some suitable watertight container at once or there will be much wastage.

A $5\frac{1}{2}$ -cwt. drum, which will provide 120 gallons of solution, may well be an excessive quantity for a small job or for finishing off perhaps a few yards on a big one, and it is often inconvenient to transport the necessary amount for such a purpose in the form of solution. With a $5\frac{1}{2}$ -cwt. drum as unit package, considerable waste must occur at times, which would be prevented if smaller drums were available for use when wanted.

The strength of magnesium chloride solution used in flooring work is denoted in terms of its specific gravity. This is determined by means of an immersion hydrometer, the most popular type being graduated to register in degrees of the Baumé scale. A few firms use the Twaddell system. For purpose of comparison a table showing relative values appears at the end of this book. For convenience in reference, it is usual to abbreviate Baumé to Be and Twaddell to Tw.

The two tables which immediately follow give the actual content of magnesium chloride, in terms of the ordinary fused commercial material, in 1 gallon of solution for a range of specific gravities, and also

the amount of chloride which should be added to 1 gallon of water to yield a solution of desired specific gravity.

Strength of Magnesium Chloride Solutions

Baumé degrees.	Commercial Magnesium Chloride (hexahydrate) in 1 gallon of solution.	
	lb.	oz.
14	2	15
15	3	3
16	3	8
17	3	12
18	4	0
19	4	5
20	4	9
21	4	14
22	5	2
23	5	7
24	5	11
25	6	1
26	6	6
27	6	11
28	7	0
29	7	5
30	7	11
31	8	1
32	8	6
33	8	12
34	9	1
35	9	7

At ordinary temperature, the solution becomes saturated when it reaches 34°-35°.

Thus, from the above table it will be seen that a drum of magnesium chloride containing 616 lb. will give $\frac{616}{5\frac{1}{8}}$ or approximately 120 gallons of solution of 22° Be strength. The following table shows that

$\frac{616}{7\frac{1}{8}}$ or about $86\frac{1}{2}$ gallons of water must be added to the contents of a drum to give the foregoing quantity of solution. The additional solution bulk is derived from the volume of the solid chloride.

Preparation of Magnesium Chloride Solutions

Baumé degrees.	Quantity of commercial Magnesium Chloride (hexahydrate) to be added to 1 gallon of water.	
	lb.	oz.
16 . . .	4	1
17 . . .	4	7
18 . . .	5	0
19 . . .	5	7
20 . . .	6	0
21 . . .	6	9
22 . . .	7	2
23 . . .	7	13
24 . . .	8	10

The tables, although close enough for practical purposes, are not scientifically accurate, for they are based upon average values for ordinary commercial chloride, which has some variation in water content. When making up solution, it is better to allow less than the estimated quantity of water at first and then break down to the required strength by successive additions, with constant stirring.

Magnesium chloride of 22° Be strength has been found by experience to be the most suitable concentration for use with finishing coats in magnesite flooring operations, although there is a prevalent idea that stronger solutions promote quicker setting and give increased mechanical strength.

This matter has been investigated by the Dow Chemical Company and the information they obtained is interesting and instructive. Briefly, plastic mixes made with chloride up to 14° Be show no advantage in strength or hardness over similar mixes gauged with water alone. From 14° Be, there is a rapid increase in tensile strength, which, with 22° Be, may be 100 per cent. greater than with 18° Be solution. Above 22°, there is a further gain, but not at the same rate. There is a gradual *slowing* of setting time as chloride strength increases and not a speeding-up as generally supposed. Volume changes appear to be at a minimum with solution of about 22° Be strength. It is doubtful whether better wearing resistance is obtained by using higher concentrations although this decreases very rapidly with weaker solutions.

To demonstrate the variation in mix behaviour which is caused by change in strength of the chloride solution, it is necessary that exactly the same type of magnesite should be used throughout the tests. Otherwise, contradictory results may easily be obtained by the use of calcined magnesites of diverse origins or with differing calcination histories, on account of the variant factors which would be thereby introduced.

It is evident therefore that magnesium chloride solution of 22° Be strength is a satisfactory working concentration both on technical and on economic grounds. Any slight advantage which might be gained by some increase of strength is hardly enough

to warrant the increased cost, while the saving which would be made by the use of less magnesium chloride is definitely not worth while because of the pronounced loss in efficiency.

The following table shows the proportion of water which should be added to solutions of higher concentration, to bring down to 22° Be strength:—

Specific Gravity in Degrees Baumé.	Solution. Gallons.	Water. Gallons.
34	4	3
32	5	3
30	2	1
28	3	1
26	5	1
24	8	1

Slightly less than the indicated quantity of water should be added and the specific gravity checked, after stirring the mixture. It can then be finally adjusted, if necessary, by the addition of a little more water. It should be noted that the temperature of the solution has an effect on its specific gravity, a warm solution giving a lower figure than a cold one. Unless the temperature variation, arising from climatic conditions, is very wide, this difference need not be taken into account.

Lower concentration, 18° Be for underlayer work and 12° Be for pre-damping sawdust, may be prepared from normal 22° Be solution, by adding 1 volume of water to 4 volumes of the latter for 18° Be and by adding an equal volume of water for 12° Be.

CHAPTER VII

ACCESSORY MATERIALS

Sawdust and Wood Flour.—In the usual type of composition floor, one or other of these materials provides the principal part of the aggregate. Sometimes the two are used together. Sawdust alone forms the aggregate in cheap single-layer work, but some firms, with the object of getting a better finish, use wood flour only, except for the underlayer. It is probable that the mixture of a limited amount of sawdust gives increased strength. Small proportions of other substances, such as silica, talc, etc., are often incorporated, but straight mixes of magnesite and wood flour, with no further additions other than pigment, are favoured by many floorlayers.

Little attention appears to be given to securing standardisation of this important part of the mix, particularly in the case of sawdust, which is a by-product. Accumulations at sawmills are often of mixed origin and it should be realised that the nature of the wood has some bearing on the resilience, hardness and strength of a floor.

Some woods are more absorbent than others and more magnesium chloride solution has to be added to the mix, to obtain the right degree of consistency.

Sawn lumber, if it has not been seasoned in a dry atmosphere, may contain as much as 45 per cent. of water. The content may be under 10 per cent., if the wood has been intensively seasoned by kiln treatment. Sawdust may therefore vary considerably in moisture content, and although this is not important when it is used for the underlayer, it may disturb the balance of a dry mix. It not only upsets the ratio of the components by weight, but the presence of water in the sawdust also causes dilution of the magnesium chloride solution.

Highly resinous woods, such as fir, are not desirable for including in magnesium mixes. As a general rule, sawdust from soft woods is preferable to that from hard, and pine is as good as anything for general use. The relative resistance to wear which various timbers offer when in the form of flooring boards, is not a guide to the resistance of a magnesium oxychloride matrix, embodying sawdust from these timbers. It is important that sawdust should always be of uniform quality, and this is not likely to be the case if it arrives in haphazard parcels and is of unknown origin.

There is not the same risk of chance variation with wood flour, which is usually a manufactured article, sold in several grades of quality. It is better, however, to keep to one grade which has been found to give consistently good service. In the event of a change in supply, test mixes should be made of the new material, before adopting it for regular use, as small modifications in procedure may be advisable.

Lightness of tint is an advantage, so that flooring colours, such as yellow and green, should not be impaired.

Sieving tests should be made from time to time. The actual figures, within reasonable limits, are not of special importance, so long as there is no wide variation in periodical supplies. A regular check on moisture content is also desirable.

In Continental practice, standards for sawdust and wood flour, for use in control tests on magnesite mixes, are specified. Both materials must be of pinewood, with normal resin content, and must have been stored for some time in an atmosphere of 60 per cent. relative humidity. The fineness standard is as follows:—

Sawdust.

Particles from 0	to 1 millimetre	.	.	50 per cent.
"	" 1	" 1.5	"	10 " "
"	" 1.5	" 2.0	"	40 " "

Plus or minus tolerance of 4 per cent. is allowed.

Wood Flour.

Residue on sieve No. 15	.	.	.	3 per cent.
" " " No. 60	.	.	.	15 " "
" " " No. 70	.	.	.	10 " "

Plus or minus tolerance of 2 per cent. is allowed.

The approximate British equivalents for these standards, in size of mesh, is: No. 15—0.014 inch; No. 60—0.010 inch; No. 70—0.007 inch.

Cork.—At one time it was thought that granular or powdered cork could be used as an aggregate in place of wood fibre, and although a number of floor-

ing manufacturers have tried this, with more or less success, it has not come into general use.

As would be expected, cork makes a warm and resilient floor, but it is not easy to work. On test samples embodying it, the resistance to wear has proved satisfactory, but in actual use, especially if subject to heavy traffic, cork-filled flooring has a tendency to pit and roughen.

In addition to fibrous aggregate in the form of sawdust or wood flour, it is often customary to add a few units per cent. of fine mineral filler, and it is in this respect that the chief variation occurs among the formulæ of floorlaying firms. Some manufacturers incorporate more than one type of mineral filler in their compositions. The materials for this purpose in common use are as follows:—

Silica.—Commercial silica is prepared by grinding quartz or flint and probably provides the most satisfactory mineral filler. It should be a little more finely ground than the magnesite, but excessive fineness, such as 300-mesh size, is not an advantage.

Silica does not function as a chemical agent in the mix, but assists, as a carrier, in bringing the oxy-chloride medium into closer contact with the particles of woody aggregate, so ensuring a firmer and more homogeneous texture.

It increases wearing resistance and mechanical strength and decreases the porosity of the flooring material, which loses much of any tendency to be absorbent. Silica is used in much greater proportion in flooring mixes in the United States than in

this country, 20 per cent. and more, by weight, being quite a usual addition.

Asbestos.—Few of the so-called asbestos composition floors contain this component to an extent which means a substantial replacement of the sawdust or wood flour, but an inclusion of short fibres or powder, up to 2 or 3 per cent. of the mix, is sometimes made. The asbestos should be well screened and of even colour. Some grades of the commercial material are rather susceptible to attack by magnesium chloride solution. When this happens, a characteristic glaze appears on the trowelled surface, which becomes very hard, and it is better not to use this type.

Asbestos, especially in powdered form, makes a mix easier to work. With increasing proportion, the floor becomes harder and more stonelike but less resilient. Long fibre asbestos imparts high wearing resistance and has some effect as a reinforcement. This is not shown by any gain in tensile strength, but there is often a marked increase in transverse strength. Absorption is greater in a floor containing asbestos than in one where silica alone is used as a filler.

Talc.—When this is incorporated in the mix, it acts like powdered asbestos and makes trowelling an easier operation. As with other mineral fillers, it helps consolidation but lowers resilience, compared with a straight wood mix. It does not impart the same increase of wearing resistance or mechanical strength that asbestos does. Excess of talc makes a floor soft and slippery.

Fillers which are occasionally used and form part of so-called secret compositions, are chalk, china clay or kaolin and kieselguhr. Although these may have no particular merits and, in some cases, are not so satisfactory as the other fillers mentioned, they serve their purpose. Kieselguhr, for example, is a form of silica and consists of the silicious structure of micro-organisms. It does not appreciably decrease the porosity of a floor nor does it impart the wearing resistance or mechanical strength that is obtained by the use of powdered quartz or flint. Its effect on a flooring mix is more comparable with that of talc.

For consistent results, it is far better that mixes should be compounded by weight and not by measurement. It may however be of value occasionally to have some idea of the relative volume weights of the usual materials handled. The following figures give the loose or unconsolidated weight per gallon of a series of typical commercial products. They form an approximate guide, but it must be appreciated that different samples of the same class of material will show some variation in volume weight.

				Weight per gallon.	
				lb.	oz.
Calcined magnesite	.	.	.	7	10
Sawdust	.	.	.	1	15
Wood flour	.	.	.	1	7
Silica	.	.	.	9	9
Asbestos powder	.	.	.	5	0
Talc	.	.	.	5	0
Fine white sand	.	.	.	13	14

Pigments.—There is probably more variation in quality among pigments than among any other of the accessory components used in magnesite flooring mixes. This affects not only their staining power, which is the measure of the amount of pigment necessary to get a required depth of colour, but also their permanence.

Some pigments, such as yellows, are often of an ochreous nature and consist chiefly of clay. Inferior material of this type not only has a poor colour value but, by the addition of a considerable amount of earthy matter into the mix, may seriously upset its balance. The so-called red oxides have a very wide range of quality, from a crude ochre up to a treated product consisting largely of pure oxide of iron. Chrome green is an oxide of chromium and is one of the most expensive pigments used by the floorlayer, but there are cheap green colours made up of a mixture of yellow ochre and Prussian blue. When mixed with calcined magnesite, the blue constituent is wholly or partly decolorised and a dirty greenish-yellow hue is the result.

The better the grade of pigment, the more resistant it is to the effect upon it of the active agents in the mix. A slight loss of colour is unavoidable in the course of time, but this may be reduced to a minimum by using good-quality pigment in adequate proportion. Pronounced fading, for example, from a red to an unpleasant pink, is a sign of the use of cheap and unsatisfactory colour.

Pigments should be tested for any sign of reaction

with magnesium chloride and also for their permanence when exposed to strong light. With the exception of black, they should be of mineral or inorganic origin. Absorbent material, impregnated with dye, which is sometimes offered as a pigment for floorlaying use, is quite unsuitable and should be rejected.

Although a high price is not necessarily a guarantee of quality, the consumer does get, as a rule, from reputable suppliers, what he pays for. Very cheap pigments are almost invariably bad.

CHAPTER VIII

FOUNDATIONS AND SUB-FLOORS

COMPOSITION flooring is essentially a floor finish and rarely forms a structural factor in a building. Occasionally, when it is used as a renovating covering on old wooden floors, an increase of mechanical strength is imparted, by reason of the high tensile strength of the oxychloride medium, but although the material provides an excellent wearing surface and introduces decorative and hygienic properties, it takes practically no part in holding a building, or any section of it, together.

Magnesite flooring can be successfully laid on many types of base or sub-floor, but certain precautions are necessary. The base should be sound and rigid, free from rising damp and not unduly porous. It should contain no free lime. Concrete, in which lime has been used as a fattener, is therefore not suitable.

Protection of Metal-work.—Magnesium chloride has a corrosive effect on some metals and there should be no direct contact between the oxychloride mix and any unprotected structural steel, conduits, pipes, etc. Preventive measures should be taken to ensure

that no chloride solution reaches any such material by percolation through the concrete.

All metal likely to come into contact with the composition should be well protected by the use of some form of anti-corrosive paint. Bituminous paints are frequently used for this purpose and, on the whole, have proved satisfactory.

Concrete containing steel reinforcement is usually well consolidated and, if the metal has been effectively painted, there is little risk of corrosion. If the whole surface of such concrete is treated with bitumen paint, as sometimes recommended, adhesion of the oxychloride material will probably be unsatisfactory. There are proprietary preparations containing bitumen, which, it is claimed, are free from this objection, but many floorlayers consider that special precautions of this nature, over reinforced concrete, are unnecessary.

If filler-joists are used, these should be well painted before the concreting is done. Exposed tops should have an additional coat. If the joists are covered, the overlying concrete should be at least $1\frac{1}{2}$ inches thick and the surface treated with bitumen composition or protected with roofing felt to a width extending 6 inches either side of the joist flanges. There is a tendency for longitudinal cracks to form in the concrete over such joists, which necessitates strip reinforcement in the composition flooring. Reference to this will be made later, when laying operations are described.

All buried conduits, pipes, etc., should be painted before installation. If intended to carry hot water or steam, in which case they would be, usually, in trenches or tunnels, they should also be well lagged with insulating material. Pipes emerging through the surface of the floor should be protected with loose-fitting, well-painted metal sleeves, which should continue for at least an inch above floor-level.

Concrete.—Properly laid concrete provides, in many respects, the best base for a composition overlay. The concrete should be substantially of 1 part cement, 2 parts clean, sharp sand and 5 parts good rubble. Certain types of aggregate, sometimes used on account of their lightness, such as pumice, breeze and clinker, are not permissible when in direct contact because of their porosity. For the same reason, aerated concrete makes an unsatisfactory base. The objection on account of porosity may often be overcome by applying a sound cement-sand screed.

Well-rammed hardcore forms a good foundation for the concrete. If for any reason concrete has to be laid directly on the ground or over an earth filling or on any site where rising damp may occur, it should be waterproofed and careful examination should be made before any steps are taken to lay a composition floor upon it. A permanently damp base means inevitable failure.

The surface of the concrete should be level but rough, so that a key is provided. It could, with

advantage, be raked or brushed over, while still plastic, with this object in view. Ordinary spade finishing, however, furnishes quite a suitable surface. If the sub-floor is not level, an unfair task is imposed upon the floorlayer, who may have to make up to a true level with his composition, at extra expense for labour and material.

There is a general prejudice against laying a composition floor on a screeded surface. The preparation of concrete floor foundations is an early stage in the history of a building and, in the course of later operations, the surface becomes littered with rubbish and dust and splashed over with plaster, paint and grease. Unless this is thoroughly cleaned off, the cement screeding cannot properly adhere and will tend to rise, leaving hollow areas, or even to break away in patches, particularly if there is any strain upon it from the pull of a slightly expanding oxychloride mix.

If a well-mixed screeding, of, say, 1 part of cement to 4 parts of washed sand, is applied to a really clean concrete base, previously damped, adhesion should be quite satisfactory. All rule-marks should be left on a screeded surface, to provide a key. It is better, however, that the floor-levels of a building should be so designed that no screeding is necessary and the concrete left in such a condition that a magnesite floor finish may be applied directly upon it.

Composition flooring should not be laid on concrete until the latter has thoroughly dried. With

ordinary Portland cement and under normal weather conditions, at least 2 weeks should be allowed.

Old, smooth concrete, on which a magnesite floor is to be laid, should be tested for soundness and any loose material removed and the surface made good. Quick-setting cement may be used for patching, to save time. The concrete should be hacked over, to provide a key.

Precautions for the prevention of absorption by the concrete of magnesium chloride from the wet mix are described later, when considering laying operations.

Flagstones, Bricks, Tiles, etc.—Old floors of this type are sometimes directly bedded upon earth and, particularly in the case of bricks, are subject to rising damp. It is possible, in some instances, to correct this by a thick cement-sand screeding, but careful examination of the conditions should always be made before any attempt is made to lay a composition floor. It cannot be too strongly emphasised that to do this over a permanently damp sub-floor will inevitably result in softening and disintegration.

If there is no risk of absorption of moisture, flagstones or bricks form a good foundation. They must be firm and well bedded down and any loose flags or bricks securely fixed. Joints should be raked out to form a key and flagstones should also be hacked over. Care must be taken, in the latter case, to chip off and remove any loose flakes. As with concrete, the surface must be thoroughly clean.

Wooden Floors.—Owing to its resilience, magnesite composition can be successfully laid on existing wooden flooring, even when this is carried on joists and therefore subject to a certain amount of movement. For this purpose, the composition is always applied in two layers, the lower and thicker being of an especially elastic nature. Reinforcement, of galvanised-wire netting or light-gauge expanded metal lathing, is embedded in the lower layer.

Unsound parts of an old wood floor should be cut out and renewed and all loose boards firmly secured. Generally the metal reinforcement, which, if not galvanised, should be well painted, is stapled or clouted down to the boards and provides an effective key. If netting or lathing is not used as a reinforcement, for example, over a solid block floor, or if it is applied between the layers of the composition, a key is provided by driving galvanised clouts into the wood floor, at intervals of about 6 inches, the heads being allowed to project for $\frac{1}{4}$ inch. Sometimes bevelled laths, with the chamfered edges downwards, are nailed to the floor at intervals of about 1 foot. In Continental practice it is usual to cover a wood floor with waterproof paper, to prevent absorption from the wet mix, but in this country the boards are pre-damped with water or weak magnesium chloride solution, and any tendency to swell on this account is largely taken up by the attached reinforcement.

Iron and Steel.—Composition flooring is sometimes

applied directly to a protected iron or steel base, as in ships' decking, railway carriage floors, stair treads, etc.

It is necessary to provide an adequate key, especially where large plates are to be covered. This is usually done by spot-welding¹ or riveting anchors, which may be of any convenient shape, to the base, at intervals of about 18 inches. On moulded steel tread-pans, an additional key is rarely necessary.

For ships' deck covering, where the total thickness of the composition may be several inches, the anchors may project proportionately. If steel strips are used as keys, they should be spaced up from the plating by using thick washers as distance pieces on the rivets.

The surface of any steel or iron foundation must be freed from loose scale and rust by scratch-brushing and cleaned of oil and grease by washing over with turpentine or other suitable solvent.

In view of what already has been said on the risk of corrosion, it will be readily understood that all iron and steel must be thoroughly protected by applying at least two coats of an effective anti-corrosive paint, which should be given ample time to dry.

¹ See *Welding Technology and Design*, No. 2. Griffin's Industrial Textbooks.

CHAPTER IX

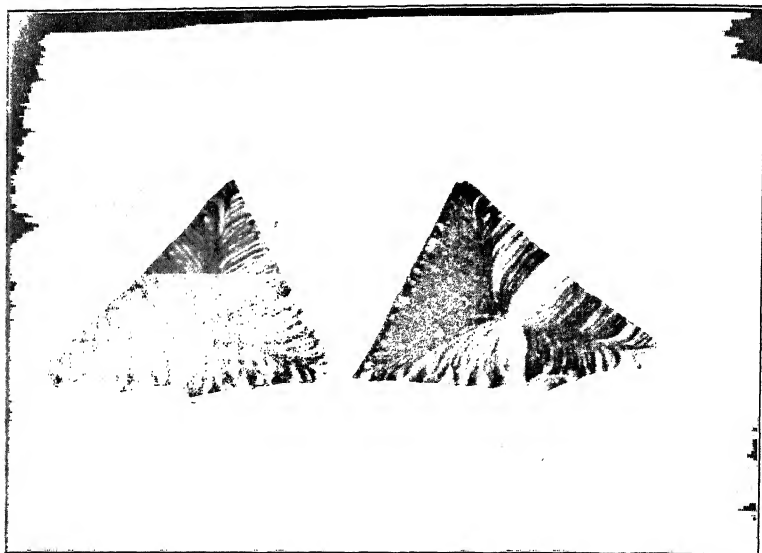
WORKS AND FIELD EQUIPMENT

THE equipment for composition floorlaying is comparatively simple and comprises facilities for storage and mixing at the works, together with tools and other appliances for use on the site.

The Works.—It is an advantage for the works accommodation to be all on a ground floor, to avoid unnecessary handling of material and, possibly, the expense of a mechanical hoist. The extent of effective floor space is dependent upon the amount of work to be done, but an area of, say, 4,000 square feet, divided into two intercommunicating rooms, one chiefly for dry mixing and the other for storage, should be ample for a business of moderate size. This is for factory purposes, and some provision should be made for a small works office and a testing-room, where samples could be prepared and such simple tests made, as the facilities available permitted.

Storage of Dry Materials.—Most of the dry materials arrive in bags and are usually kept in these until required for use. Pigments are packed in casks or

plywood kegs, which provide convenient storage. Care should be taken that all pigment containers are properly covered, when not being used, to protect from dust. All materials should be stored under as dry conditions as possible. Calcined magnesite



[Photo : A. F. Green.]

FIG. 5.—Yugoslavian Magnesite.
Characteristic appearance after calcination.

particularly will very quickly deteriorate if exposed to a humid atmosphere. Some firms make a practice of emptying the bags of magnesite into a bin and storing in bulk for a fixed period before use, with the idea of standardising the rate of set. As magnesite does not necessarily reach the consumer at consistent intervals after calcination, there does not appear to be any special advantage in this pro-

cedure, unless tests are made for ignition loss and storage conditions adapted to maintain this figure as nearly as possible constant, for successive batches of magnesite, at the time of use.

Tank for Magnesium Chloride Solution.—Magnesium chloride is supplied in steel drums holding about $5\frac{1}{2}$ cwt. The material forms a solid core and can only be unpacked by stripping the drum from it. Magnesium chloride very rapidly takes up water, even in an apparently dry atmosphere, and once a drum is opened up, the whole of its contents should be transferred to a dissolving tank. Occasionally, small quantities of broken solid chloride have to be sent out to a job in circumstances where it is not practicable to transport solution. In such case, a clean galvanised dust-bin, covered with a piece of sacking and the lid fitted tightly over this, forms a convenient container.

Although most of the consumption of chloride will be away from the works, a stock of solution should be kept at headquarters and a tank must be provided. A drum of chloride will yield about 120 gallons of 22° Be solution, but the concentration in the tank may be allowed to exceed this strength, as it can readily be diluted down as required. A galvanised-iron tank, 4 feet by 4 feet by 4 feet, which contains 400 gallons, is a useful size. It should be mounted on a low platform and fitted with a tap set about 2 inches above the inside bottom, to allow for deposition of sediment. Smaller gal-

vanised tanks or clean oak barrels may be used to supplement the dissolving tank, for preparing solution of any required specific gravity.

Hydrometers.—The specific gravity of magnesium chloride solution is tested by means of an immersion hydrometer. The usual form for works purposes is about 9 inches long and if Baumé's scale is used, a range from 0° to 40° , graduated in quarter degrees, will be quite suitable. A 6-inch instrument is a more convenient size for bench work, where checks may have to be made on small quantities of solution. It is, perhaps, as well to mention that there are also Baumé hydrometers similarly graduated, but for liquids lighter than water. These are useless for solutions of magnesium chloride.

Some floorlayers prefer the Twaddell scale of specific gravity, but this does not usually cover so wide a range in one instrument and, to be able to test all concentrations, from that used for pre-damping sawdust for underlayer work, up to the saturated solution which might be formed in the dissolving tank, a set of three hydrometers would be needed. This, of course, is equivalent to an extended scale graduation and provides greater accuracy. The middle one of the three, registering from 24° to 48° Tw, covers most of the strengths for flooring work and roughly corresponds with the range between 15° and 28° on the Baumé scale.

Dry Mixing.—Practically all mixing of dry com-

ponents should be done by mechanical means and a mixer is an essential part of the works equipment. The type with a fixed drum and a revolving multi-spiral stirrer, set horizontally, is as good as any. The largest size for hand power will thoroughly mix about $1\frac{1}{2}$ cwt. of dry composition in 15 to 20 minutes.

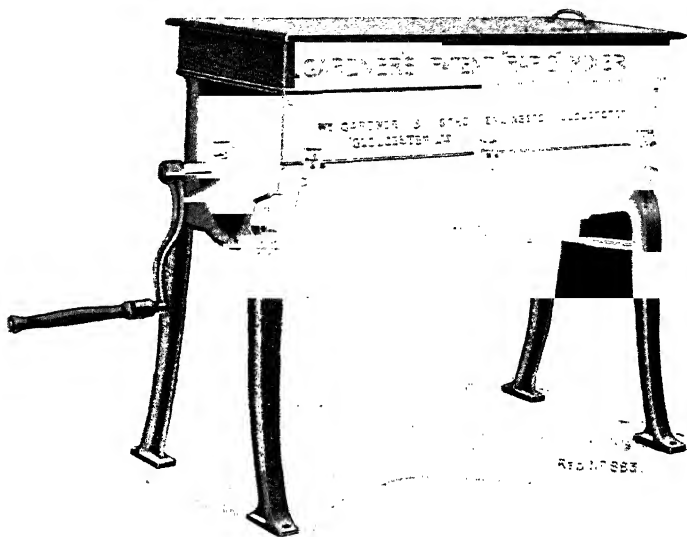


FIG. 6.—Rapid Mixer.

If greater quantities are required, then a mixer of similar pattern but of higher capacity, with a power drive, can be installed.

Weighing.—All materials should be compounded by weighment and a platform weighing machine, carrying at least up to 3 cwt., should be provided.

This should be supplemented by scales or a spring balance with pan, weighing to 14 lb.

Floor for Pre-damping Sawdust.—Coarse sawdust, for the underlayer, is pre-damped with weak magnesium chloride solution, before use. A conveniently situated space on the floor, with a good, smooth, impervious surface, should be reserved for the purpose. This may be partly enclosed, with advantage, to form a large bin, but room must be available for turning the heap, to assist saturation.

General.—In the works equipment there should be a supply of the usual small appliances, whose employment is obvious. These include barrows, shovels, brooms, buckets, sieves, etc.

Requirements at Site.—Apart from the mixing of dry materials and the pre-damping of sawdust, most of the floorlayer's work is conducted away from his base. His usual equipment consists of the following articles :—

Galvanised tank for dissolving magnesium chloride, of about 100 gallons capacity, or larger, according to size of job and number of men employed.

Barrel or smaller tank, 40 gallons capacity, for diluting solution to working strength.

Wooden mixing trough, about 6 feet by 3 feet by 2 feet high, with sloping ends and sides.

Kneeling board.

$\frac{1}{2}$ inch and $\frac{1}{4}$ inch battens—8 feet long, for screeding.

8 feet Straight-edge.

33 feet Measuring tape.

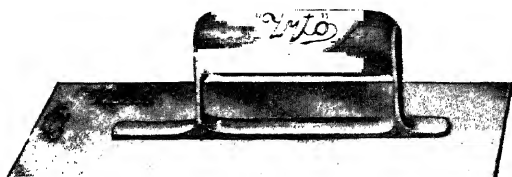


FIG. 7.—Laying-on Trowel.

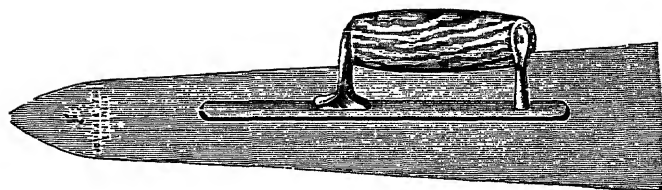


FIG. 8.—Floorlaying Trowel.

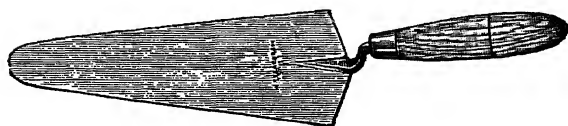
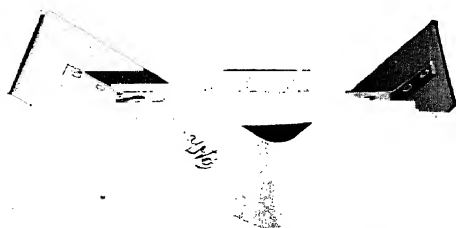


FIG. 9.—Gauging Trowel.



[Messrs. S. Tyzack & Son, Ltd.]

FIG. 10.—Coving Trowel.

Spirit level.

Hydrometer.

Double-shank laying-on trowel.

18 inch Floorlaying trowel.

8 inch Gauging trowel.

Coving trowels.

Tamping tool or rammer.

Scrapers—straight and curved French pattern for coving.

Strainer for solution.

Shovel, broom, bucket, hammer, etc.

The exact dimensions and form of the various trowels are dependent to some extent upon the personal preference of the operative, who usually possesses his own tools.

The coving trowels vary according to the radius of the required curve, which is normally 2 inches to 3 inches. A general-purpose trowel, for a coving of about this curvature, would measure 7 inches from centre to edge, with a width of 3 inches. For coves of smaller radius, say 1 inch to $1\frac{1}{2}$ inches, the dimensions of the tool would be correspondingly less.

A scribe and several wood chisels will be needed when it is necessary to cut away the floor for insertion of patterns or lines, and a cold chisel or steel point should be available for hacking a key over a screeded concrete or stone sub-floor, if this has not already been done.

CHAPTER X

THE DRY MIX

ALTHOUGH not universal, it is certainly a very general custom in the trade to measure by volume the proportions of the materials which constitute the dry flooring mix. Reference has already been made to the variation which may occur from time to time in the volume weight of the same class of material and also, particularly in the case of calcined magnesite, to the very different weights which may be recorded for the same sample, according to the manner in which the container is filled.

If measurement and not weighment is used for determining the proportions of the mix, repetition of consistent composition is not easily obtainable and this naturally has its effect on the ultimate quality of the floor. Undoubtedly, the best method of ensuring precise control of mix composition is to weigh out the components. There are many floor-layers, however, who have always measured out their materials and probably will continue to do so. Usually the unit is a bucket, which is not always of known capacity. If mixes are to be made up by volume, proper measuring vessels should be pro-

vided, and these should always be filled and struck under the same conditions.

Any transposition from weight to volume which may be considered here, for the purpose of comparison with existing practice, is based upon loose volume weight. This is ascertained by filling a container of known capacity with screened material, poured from a height of about 10 inches. The surplus is struck to a level, without any attempt to assist consolidation, by tamping or jarring the receiver, and, from the nett weight of contents, the value per gallon or per cubic foot can readily be calculated.

When mixing cement concrete, theoretical considerations require that the amount of cement used should completely fill the voids or inter-granular spaces in the sand and that enough of this cement-sand agglomerate should then be taken, similarly to fill the interstices in the rubble or coarse aggregate. It is not practicable to use the same principle in designing a magnesite flooring mix. If silica is included, it is usually of much the same degree of fineness as the magnesite and there is not so definite a physical basis for their respective proportions. Further, the chief component of the aggregate, whether sawdust or wood flour, absorbs magnesium chloride solution and, in doing so, swells to such an extent that its volume may increase by as much as 60 per cent. and any predetermination of its interstitial volume would therefore be of no assistance.

There is nothing especially secret in the composi-

tions used throughout the trade, and the claims made for the particular merits of individual products are generally founded upon the addition of small proportions of one or more mineral fillers.

Basically, nearly all the magnesite flooring mixes which are used in this country consist of calcined magnesite, sawdust or wood flour, pigment and magnesium chloride solution. Occasionally asbestos is used as an alternative fibrous aggregate, but rarely, if ever, wholly in replacement. Success chiefly depends upon the quality of these materials and the degree of technical skill used in their compounding and application, rather than upon the presence of other components which are introduced to impart particular characteristics to the finished floor.

Talc, for example, makes the composition easier to work and silica or asbestos gives greater hardness, at some cost in resilience. But such additions, valuable as they may be when it is desired to develop some special property in a floor, have no mysterious attributes, nor can they correct fundamental unsoundness, either in quality or manipulation.

The cheapest type of floor consists of magnesite and sawdust, but there is an increasing tendency among the better firms to replace sawdust largely, if not entirely, by wood flour, except for the underlayer in double-layer floors. Sawdust gives greater hardness than wood flour, but the latter imparts a better surface and a closer and more homogeneous texture to the composition, while preserving a resilience which is still of a satisfactory high standard.

It has already been noted that the usual practice in the trade is to make up mixes by measuring out the components. On this basis, what may be described as the stock ratio between calcined magnesite and wood flour, is usually somewhere near 6 volumes of the former to 8 volumes of the latter. There are modifications of this proportion, up or down, among different layers, but not to any marked extent. A 6-8 mix by volume corresponds to an average weight ratio of 4 parts of calcined magnesite to 1 part of wood flour. The apparently high proportion of magnesite, when considered in this way, is due to the lightness and consequent bulkiness of the aggregate. With equal weights, wood flour will occupy nearly $5\frac{1}{2}$ times the space of magnesite.

Mineral Fillers.—Within fairly wide limits, the proportion of any mineral fillers which may be added is not critical, although as none of them enters into chemical reaction, they act as diluting agents in respect to the active components of the mix, unless added in substitution of an equivalent amount of other aggregate. It may be said, however, that if the 4-1 weight ratio between magnesite and wood flour is substantially maintained, the addition of as much as 15 per cent. silica, if an especially hard-wearing floor is desired, does not interfere with the cementitious effectiveness of the mix and, with some qualities of magnesite, it may be an advantage.

Such additions as are made arise from personal preference and, in most cases, their justification fol-

lows experience of their use. Occasionally, components such as china clay or kieselguhr are added to a mix, to warrant a claim for special merits, which are then emphasised for commercial purposes.

There is advantage in the judicious use of small proportions of mineral fillers, with a view to obtaining particular qualities in a finished floor. Silica may usefully be added to a mix when the floor is likely to be subject to heavy wear and is laid on concrete or other rigid base. It is not a desirable addition when the composition is to be laid, for example, on an old wooden floor where a certain amount of movement may be expected, for, in this case, maximum resilience is sought. Talc may be used as a fatter, to assist trowelling, when a non-absorptive surface, with a smooth finish, is sought. If high transverse strength is wanted, then the addition of medium fibre asbestos is an advantage. Apart from silica and in some instances asbestos, the amount of mineral filler does not usually exceed about 5 per cent. of the mix.

Pigments.—These vary so much in quality and staining power, that no hard-and-fast rule can be given for the quantities to be used. The cheapest pigments not only have to be added in relatively large proportion to attain the desired depth of colour, but they lack permanence because of their non-resistance to chemical attack by magnesium chloride.

Experience is the best guide and it is always a simple matter to try a few test pats with varying amounts of pigment. It should be remembered that there is always some loss of colour value with the passage of time, but the better the quality of the pigment, the less is this fading likely to be. Preliminary bench tests should always be made if, for any reason, there is a change in the source of supply or if the regular grade of pigment is replaced by another.

Particular care should be taken when using green and blue pigments. These are the most expensive colours to buy and on this account there is sometimes a tendency to cut down the amount used. This is wrong policy, as it is impossible to get a pleasing result with either of these, unless an adequate proportion of pigment is used in the mix.

According to the quality of pigment and the depth of colour desired in the floor, the amount required in the dry mix will usually be found to range from $7\frac{1}{2}$ per cent. to 15 per cent.

Mix Formulation.—It should be apparent that, if certain fundamental conditions are fulfilled, some latitude is permissible in composition. No single formula can be put forward which would give the best results in all circumstances and those which are mentioned here may be taken as fairly representative of the type of composition used in good-class work. The proportions are stated by weight, but average

volume equivalents are also given to provide a means of comparison for those floorlayers who hitherto have always worked by measurement.

	By weight. Per cent.	Approximate equivalent by volume. Parts.
<i>Under-layer.</i>		
Calcined magnesite .	50	1
Dry coarse sawdust.	50	4
<i>Single-layer.</i>		
Calcined magnesite .	70	12
Sawdust . . .	15	10
Wood flour . . .	7.5	7
Pigment . . .	7.5	1

The above is the cheapest mix for satisfactory single-layer work.

Single-layer and Hard Finishing Coat for Double-layer Work.

Calcined magnesite .	60	6
Wood flour . . .	15	8
Silica . . .	12.5	1
Pigment . . .	12.5	1

Finishing Coat for Double-layer Work on Wood Boards.

Calcined magnesite .	70	9
Wood flour . . .	17.5	12
Talc or powdered asbestos	2.5	$\frac{1}{2}$
Pigment . . .	10	1

Finishing Coat for Mottle Work.

Calcined magnesite .	70	6
Wood flour . . .	17.5	8
Pigment . . .	12.5	1

United States Practice.—It is interesting to note that magnesite flooring practice in the United States is based upon different principles of mix composition

and a high proportion of silica is used. The standard flooring mix, adopted by the Dow Chemical Company for their investigations and which approximates closely to the average commercial mix, has the following composition:—

	By weight Per cent.
Calcined magnesite	46
Silica	27
Talc	9
Fibre (wood flour, saw- dust or asbestos)	9
Pigment	9

Without considering in detail this departure from the customary British standard, it is sufficient here to say that a floor of this type is considerably less resilient than one in which the aggregate is mainly wood flour, but it is harder and more resistant to abrasive wear. Also, when comparing the proportion of magnesite used, it should be noted that the formula in use in the United States results in a much heavier composition and there is consequently a greater consumption of material, by weight, per square yard.

Continental Practice.—The following two mixes are recommended by the Austro-American Magnesite Company and the proportions are stated by volume:—

	Approximate equivalent by weight. Per cent.	Parts by volume.
Calcined magnesite .	69.4	8
Wood flour . . .	22.7	14
Sawdust	2.2	1
Talc	5.7	1
Calcined magnesite .	72.5	8
Wood flour . . .	22.25	15
Asbestos	5.25	1

These mixes are unpigmented and any colour added must be in replacement of an equivalent part of the aggregate. It will be noticed that they are weaker than is customary in British practice and resilience appears to be the chief property sought.

CHAPTER XI

THE WET MIX

WHEN the dry mix is gauged with a solution of magnesium chloride, of suitable strength, magnesium oxychloride is formed, the setting process comes into operation and the aggregate is bonded together. This is a simple description of what is really a complex chemical reaction, which can only be adequately considered in terms of pure science.

It must not be assumed that the whole of the calcined magnesite present in the mix is converted to oxychloride. If this were so, then in accordance with the most probable formula for stable magnesium oxychloride, every 3 lb. of magnesite would require 5 lb. of ordinary fused magnesium chloride, or about 1 gallon of 22° Be solution. This is apart from the amount of solution which is absorbed by the aggregate and is not available for early reaction.

Water is also an active agent and combines with a considerable proportion of the magnesite to form a hydrate, which also has some part in the setting process and binding properties of the composition.

A detailed study of the various chemical questions which are involved would be of very little assistance to the practical floorlayer, who, quite reasonably,

does not concern himself with any complex theoretical aspects which may be behind his operations. His object is to secure results by methods which intelligently applied experience has proved to be the most suitable for the purpose.

It must not, however, be assumed that composition floorlaying procedure has a purely empirical basis. Quite apart from the complexities of the oxychloride reaction, there are well-defined principles which come into operation and to which reference has been made from time to time in the earlier sections of this book. Some of these principles have their application in the preparation of the wet mix.

It has already been shown that the most useful concentration for magnesium chloride solution has a specific gravity of 22° Be. This applies particularly to its use in single-layer floors and for the finishing coat in double-layer floors, which, in most good-class work, are of similar, if not quite identical, composition. The constitution of the mix, subject to slightly variant forms dependent upon the preference of the layer, together with the strength of the chloride solution to be used with it, may therefore be taken as practically, or within fairly narrow limits, standardised.

The consistency of the wet mix is of great importance and is determined not only by the proportion of solution to dry material but also by the extent to which the working-up of the plastic composition is carried. The degree to which magnesium chloride enters into reaction with the magnesite depends upon

the physical state of the latter, which may vary in magnesites from different sources or with irregular calcination histories, and this has some bearing on the amount of solution needed. Absorption by the aggregate is also a factor to be considered. Sawdust and wood flour take up more solution than asbestos does, while the other mineral fillers have very little effect.

It will be evident, therefore, that the amount of magnesium chloride solution to be used is not a quantitative equivalent, based upon the chemical changes which take place, and the attainment of the best degree of plasticity or consistence, for the object in view is the ruling factor. This is one of the conditions which must be left largely to the judgment of the operator and the experienced man need not go far wrong.

Various forms of control tests have been suggested, but these are more valuable for repetition of conditions for laboratory work than for use in actual practice. The degree of plasticity for the standard flooring mix in the United States, which has a high content of silica, requires that the wet material should just support a cylinder of 1 inch diameter, weighing 250 grammes. For those who care to make the test, it may be said that a pile of 22 pennies on 8 halfpennies will fulfil the conditions for base diameter and weight.

So long as a mix can be satisfactorily worked after being laid, stiffness is an advantage. It results in a better floor, harder wearing and less prone to

sweating or efflorescence, but trowelling is more laborious than with a more fluid mix. On this account, there is unfortunately a temptation to add more solution than is necessary, to make the later work easier. Too wet a mix causes a segregation of the components under the trowel, with the result that the floor acquires a hard skin but has very little strength or wearing resistance underneath and its life can only be a short one.

The advantage of wet mixing by mechanical means is sometimes urged, but the provision of a special mixer on the site is not only impracticable but is unnecessary. Trough mixing, if conscientiously done, is nearly, although not quite, as efficient.

The amount of magnesium chloride for a given weight of dry composition cannot be stated with close accuracy for the reasons already mentioned and some adjustment in the quantity, up or down, is usually necessary for each batch of mix. It should be possible, however, to estimate requirements sufficiently closely for costing and the provision of materials. In this respect, every floorlayer has his own experience as a guide. Notwithstanding this, there is a surprising divergence among practical men in their ideas of what chloride consumption actually should be.

These differences are undoubtedly due, in some part, to variations in mix composition, but there does not appear to be a generally accepted standard for the normal plasticity of the wet mix. It is also possible that routine consumption of materials is not very closely regulated or recorded.

The following figures will give an indication of values for mixes of the types already mentioned, but allowance must be made for diversity of individual practice. For example, a mix containing a relatively high replacement of sawdust or wood flour by silica, will be less bulky than one containing little or no silica and will have lower covering power in relation to its weight. It will also require less magnesium chloride solution.

Under-layer.—Nominal $\frac{1}{2}$ inch thick ; 10–12 lb. mix (based on dry weight) per sq. yd. 1–1 $\frac{1}{2}$ gallons 18° Be solution.

The sawdust should be pre-damped before mixing and this will take 1 gallon 12° Be solution for every 6 $\frac{1}{2}$ –7 gallons coarse, dry sawdust, which will swell, according to its absorptive capacity, to a maximum of about 60 per cent. increase on its dry volume.

Single-layer.—Nominal $\frac{1}{2}$ inch thick ; 14–18 lb. dry mix per sq. yd. 1 $\frac{1}{2}$ –1 $\frac{3}{4}$ gallons 22° Be solution.

Double-layer Finishing Coat.—Nominal $\frac{1}{4}$ inch thick ; 9–10 lb. dry mix per sq. yd. About 1 gallon 22° Be solution.

CHAPTER XII

LAYING PROCEDURE

At the Works.—Mixing the dry and plastic material and the treatment of foundations need a high degree of knowledge and care, but the practice can be described in some detail and is easily taught to an intelligent worker. The actual laying process is a very different matter and the description which follows later is not intended to serve as a guide to an untrained man, without previous experience of the material to be handled. It may, however, enable the architect, or other interested person, to assure himself that the various operations are being carried out in a workmanlike manner and with real knowledge of what is involved.

The necessary preparation at the works, for a job outside, consists chiefly in compounding the dry mix and the pre-damping of sawdust required for the underlayer in double-layer work. Magnesium chloride is sent out in the original drums, for any area over 50 sq. yds., which approximately represents the consumption unit per drum. Broken chloride, packed in suitable containers, can be sent out for smaller jobs and 10-gallon drums of solution are convenient if only a few square yards have to be covered.

The advantage of a tap, fitted 2 inches above the bottom of the tank, to allow for deposition of sediment, has already been noted when considering equipment. The tank should be kept covered and solution may be allowed to proceed up to saturation-point. Any scum which is formed should be removed from time to time and always before dipping out solution, if no tap is provided. The solution drawn from the dissolving tank should be passed through a haircloth or 100-mesh brass strainer before being diluted to working strength in a barrel or smaller tank. The approximate amount of water to be added when diluting down from a higher concentration is given in the table on page 39. It is better to add less than the calculated amount of water at first and then gradually add more until the hydrometer shows that the desired specific gravity is reached. The solution must be well stirred after each addition, before being tested.

The utmost care should be taken to ensure that no solution is spilt or that pieces of solid chloride, which readily liquefies, are left about on any foundation which is to serve as a base for the magnesite floor. If it is impracticable to break up the material outside the building, then a substantial ground-sheet should be employed as a safeguard.

Single-layer Flooring.—This is the cheapest type of magnesite flooring and can be applied over any of the usual foundations, except wood boards, as these are not absolutely rigid under load. If, as some-

times happens, the sub-floor levels are not true and there is any substantial correction to be made, then a double-layer floor may be more economical, as the less costly under-layer material may be used for making good and providing a true foundation for a finishing coat of normal thickness throughout.

Single-layer floors are from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch thick, as may be specified, and are laid in one operation. The foundations, which should conform with the requirements already noted in an earlier chapter, should be thoroughly cleaned and then washed over with water or chloride solution of about 14° Be strength, to prevent absorption from the wet mix. The sub-floor should remain damp after this treatment, but there should be no standing pools of solution. Some floorlayers apply a further wash of magnesite or plain mix, with weak chloride, but there is no real need for this.

In Continental practice, especially when dealing with reinforced and filler-joist sub-floors, a preliminary wash with silicate of soda solution is often applied, but the precaution is not a usual one in this country.

A bag of prepared dry mix is then turned into the mixing trough and sufficient magnesium chloride solution of 22° Be added in stages until the right plasticity is obtained. The approximate amount of solution needed will be known from experience, but this cannot be exactly gauged and the final additions must be made gradually. Towards the end of the mixing, it will be found that a very small quantity

of chloride will have a marked effect upon the consistency.

The mix must be thoroughly worked up with a shovel, care being taken that every part of it is equally impregnated with solution. It is often the custom, when the required consistency is reached, to allow the "dough" to stand for about 15 minutes, when it will begin to show signs of stiffening. This is then brought back to working plasticity by the addition of the least possible amount of solution. The procedure has a mild retarding effect on the setting reaction and the material becomes easier to handle.

While this is permissible, it may be stated here that on no account should a mix, which, for any reason, has not been used when ready and which has passed its first set, be re-tempered with fresh solution, to make it soft enough for use. The material will be worthless for its proper purpose.

Where the surface of the sub-floor is fairly even, battens of the appropriate thickness and up to 8 feet long are used as guides when laying. The plastic material is spread, with a floorlayer's trowel, as regularly as possible, to the thickness of the batten, in successive bays of about $2\frac{1}{2}$ feet wide, or a comfortable reach. The surface is smoothed, without being heavily trowelled, and the floor is left to complete its first set.

In the case of large unbroken areas, it is becoming increasingly the custom and is occasionally required by specification, to provide joints, to counteract

lateral movement in the floor, due to expansion or contraction. These may be in the form of inset strips of hardwood, metal or vulcanite, about $\frac{1}{4}$ inch thick, bedded in the plastic composition flush with the surface, or mastic insertion may be employed. A usual dimension between such joints is 25 feet in either direction.

The time taken for the first set will vary according to the class of magnesite used, the composition of the mix and the conditions of temperature and humidity during the laying operations.

When the floor is hard enough to support a board with the weight of a man on it, without being marked, it should be scraped over with a flat scraper, care being taken to remove all marks left by the trowel. The scrapings are lightly brushed off and the floor again trowelled over with a laying-on trowel. It is then left for about 12 hours, or usually all night, before washing over with chloride solution of 15° Be, which finally seals the surface and leaves it perfectly smooth.

Double-layer Flooring. Under-layer.—The preparation of the coarse mix for the under-layer is the one instance where departures from recommended practice are permissible.

- (1) The proportions may be determined by volume.
- (2) The materials may be mixed by hand at site.

This is more convenient, because the sawdust is already wet with chloride and the mix is not therefore really a dry one.

The proportions by volume, which are equivalent to equal weights of calcined magnesite and dry sawdust, will be found to be about 1 part of magnesite and between 5 and 6 parts of damp sawdust. The required volume of the latter will be found to vary slightly according to the extent of the swelling which the particular quality of sawdust in use undergoes, as a result of pre-damping.

The foundation, whether concrete or wood, should be damped, as already described, and then brushed over with a wash of magnesite and chloride solution of 14° Be, of about the consistency of cream. Some wood flour is frequently included in this wash. This should be done in strips, of a size which may conveniently be covered with composition before the wash is dry and hard.

The magnesite and sawdust are thoroughly mixed on a clean level surface and then well worked up in the trough, with solution of 18° Be. The mixture should be damp throughout, but still crumbly and not wet enough to be plastic.

This is spread over the prepared area of the foundation, using battens, which are usually $\frac{1}{2}$ inch thick, as guides. The material should be well consolidated by ramming and the surface then ruled to a true level.

The underlayer does not set as hard as the finishing coat but, by reason of its coarser texture, it forms a most efficient cushion, absorbing shocks and vibration and imparting a high degree of resilience to the whole floor surface.

Finishing Coat.—The finishing coat is applied when

the under-layer is hard enough to work upon but still is appreciably moist, which is generally between 12 and 24 hours after it has been laid. If the base coat has hardened right off and is dry, it will require damping with chloride solution to prevent absorption from the top mix. The addition of further chloride at this stage is not desirable and the necessity for it should not arise, if the working programme is intelligently arranged.

The finishing coat is laid in the same manner as the single-layer floor, with the exception that the usual thickness is $\frac{1}{4}$ inch and the guide strips must correspond. As this layer is comparatively thin, care must be taken that the full substance is maintained throughout and not fined down, as sometimes happens, by excessive trowelling or scraping, leaving in places little more than a veneer.

CHAPTER XIII

LAYING PROCEDURE (*continued*)

Mottled Flooring.—This type of floor should always be in the form of a double-layer. Although no silica is used in the mix, the stiffness of the plastic material and the thorough consolidation it receives from ramming, yields a very hard-wearing surface coat, which must be effectively bonded down. The usual under-layer is the best base for this, as direct application to the sub-floor, as a single-layer, frequently results in failure.

The colours may be in any combination desired. A contrast of two is usual and rarely more than three. Very often, the natural tint of the unpigmented mix forms part of the pattern, to give an ivory effect. There is, however, a tendency to darken with age and it is better to add a little white pigment to this part of the mix. A good titanium white is best for the purpose.

The coloured mixes are gauged with 22° Be solution separately in the trough, which should be cleaned after each batch has been handled. It is better to have two or three troughs available for this work. The plasticity should be such that if a handful of wet mix is squeezed, the solution just seeps through

the fingers. If wetter than this, there is a risk of the colours running together and the sharp contrast, which is so effective in the pattern, will be ruined.

Each of the plastic mixes is then worked through a sieve of $\frac{3}{8}$ -inch mesh, to obtain a heap of damp pellets, of practically uniform diameter. If desired, a larger or smaller mesh can be used for sieving one

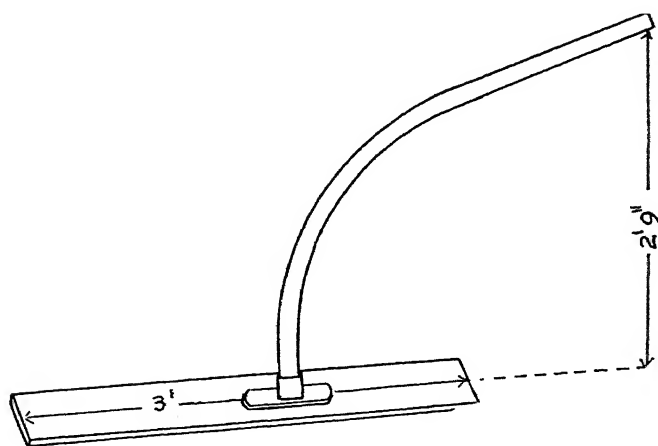


FIG. 11.—Floorlayer's Rammer.

colour, to obtain a contrast in size, in the pattern. The two or three heaps of coloured pellets are then mixed together, in their proportionate quantities, by shovelling to and fro. This should be done carefully, so that, as far as possible, the pellets remain unbroken. If a ringed or veined effect in the pattern is intended, the pellets should be dusted over, before mixing together, with a dry mix of the veining colour,

which should contain a little more magnesite than the normal proportion.

Unless the under-layer is moist, it should be damped over with a wash containing wood flour, similar to that used originally on the sub-floor. The further addition of chloride solution here is not objectionable because the mix to be applied after the wash contains less than is usual for ordinary trowel finishing.

The mixture of pellets is then lightly spread over

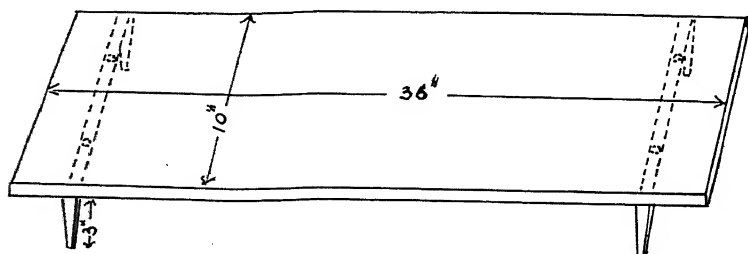


FIG. 12.—Kneeling Board.

the base, to a thickness of $\frac{5}{16}$ inch, with the help of a straight-edge, the tender material still being carried and handled with care. The layer is consolidated by ramming with a special tool (Fig. 11). The exposed pellets are then worked into contact and the surface closed, by trowelling, the floorlayer using a kneeling board with short peg legs (Fig. 12).

After 12 to 18 hours, according to the conditions of temperature and humidity at the time, the floor ought to be ready for scraping. It should be tough enough to prevent the pellets being dragged out, but not too hard for vigorous scraping. All blurring and

smears caused by the trowel must be scraped away and the sectional character of the pattern developed.

Eight to ten hours later, the floor should again be lightly scraped to remove scratches and to bring out the effect of the design to the fullest extent.

Marbled Flooring.—In many respects, this is laid similarly to an ordinary double-layer floor, except that the mix for the finishing coat is made a little

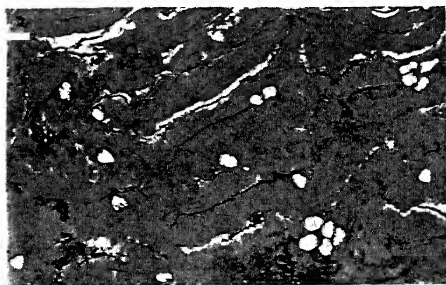


FIG. 13.— Simple Marble Pattern.

stiffer, although not so stiff as that used for a mottled floor.

The $\frac{1}{4}$ -inch finishing coat must be laid true, without the use of guide battens, as they may cause a junction line to show along the edge of each strip of floor and so spoil the effect. The veining is obtained by dusting with a mixture of magnesite and pigment, to an irregular design and lightly trowelling in.

Reinforcement.—It is not necessary to apply reinforcement to the whole area of a composition floor

laid on a rigid base, such as concrete, and this need not be considered in respect to single-layer work. It is occasionally advisable to use local reinforcement, as, for example, in the case of a filler-joist sub-floor, where there is a tendency for cracks to develop in the concrete along the line of the joists. Roofing felt is sometimes used for the purpose and also serves to prevent percolation of the chloride solution, but the usual practice is to apply strips of 1-inch mesh galvanised netting or the lightest gauge expanded metal lathing. The strips should extend several inches on each side of the joist and be wired end to end. A thin layer of plastic mix is spread along the line of the joist and the reinforcement bedded in. The floor is then finished in the usual way.

Reinforcement for a double-layer floor on wood boards is used over the full extent of the floor. The netting or lathing is fastened to the boards with galvanised staples or clouts and provides an effective key. The under-layer is then laid and consolidated by tamping.

If lathing is used, it should first be given a good coat of suitable paint. The ordinary thin covering applied by the makers is not sufficient protection against corrosion.

Coving and Dados.—The advantage of a cove or curved junction between floor and base of wall is obvious and magnesite composition is particularly adaptable for making this. The cove may be continued up the wall, to form a dado.

Direct contact between the oxychloride mix and the wall plaster should be prevented by the use of an intervening fillet of wood, Portland cement or other suitable material.

The existing plaster should be first cut away to the intended level and the coved skirting finished flush with the protecting fillet or, if it is to project, it can be laid up to a temporary guide formed by a batten tacked to the wall and the edge chamfered later.

Skirting and dado may be applied directly on to brickwork, or preferably over a rendering of Portland cement. A coarse base coat is not usually necessary for dados, but a double-layer floor is continued in this form to the top of the skirting. The cove is shaped with the special curved trowel (Fig. 10) and is afterwards scraped to a smooth finish with a French pattern scraper.

Borders, Patterns and Lines.—When a contrasting border, which may include a coved skirting, is intended as a surround, it is usual to lay this first and finish it. The edge is then marked off with a chalk line and scribed, as a guide for trimming true with a chisel. Before the centre area is filled in, the surface at the edge of the border should be lightly treated with wax polish, to prevent adhesion of any of the new mix, as this cannot afterwards be removed without marring the clean line at the junction.

For inset patterns and lines, the whole floor should be laid and finished. The design is then scribed and

cut out. The same precaution to protect the edge should be taken, before filling in the coloured mix which is to form the pattern. If several colours are to be employed in the design, these should be laid successively and allowed to harden, trimming the edge to shape before each addition.

To obtain the full value from any contrasting border or inset design, it is essential that all lines should be clean and true and angles sharp, otherwise the work will look slovenly.

Ships' Decking.—The application of composition flooring to steel decks is a specialised branch of the industry. Reference to protective measures against corrosion and the need for provision of an effective key has already been made in an earlier chapter.

Coarse sawdust forms the chief part of the composition, which, in places, has to be several inches thick, lightness being a desirable quality. The abnormal thickness is partly due to the need for insulation against the transmission of heat but mainly to the uneven nature of the foundation. Corrections for strapping or lapping, at the joints of heavy deck plates, require considerable variation in the depth of the applied composition, so that surface may be uniformly level.

It is not always necessary to lay a fine finishing coat, because the composition is often intended only to provide a suitable surface to carry some other type of floor-covering, such as carpet or tile.

General Considerations.—It sometimes adds to the appearance of a large expanse of plain floor if it is scored into squares, with sides of 2 or 3 feet. This should be done soon after the final set and the lines must be clean and straight, crossing at true right angles.

This minimises the rather patchy effect which certain colours, for example green, tend to give. If the scored lines are spaced so that they coincide with weak places in the concrete sub-floor such as occur over bedded joists, they will take any fine cracks which, although mechanically unimportant, might otherwise spoil the appearance of a highly finished surface.

During the process of laying, the floor should be kept at as even a temperature as conditions permit. It should not be exposed to the action of the weather and, as far as possible, be shielded from direct sunshine. It is not reasonable to expect a floorlayer to do a satisfactory job in a windowless, partly roofed structure, as sometimes has happened, and fair conditions for carrying out the work should be specified in the contract.

Composition floorlaying should be the last work to be done in a building. The material is readily susceptible to injury for some time after it is laid, and if electricians, plumbers, etc., have to carry out their operations on it, or in its near neighbourhood, while it is still tender, serious marring of the surface is almost certain to result.

CHAPTER XIV

AFTER-TREATMENT AND DEFECTS

After-treatment.—When the floor has been washed in, it is usual in British practice to give it a final surfacing with No. 3 steel wool, as a preliminary to a dressing with equal volumes of linseed oil and turpentine.

It will be seen from the curves (Fig. 14), which show the rate of drying of composition flooring, that for about 5 weeks after the final set, there is a steady loss by evaporation of surplus moisture, and this is followed by a slight but steady gain in weight by absorption. These tests were made on unoiled samples, kept under winter conditions in a dry but unheated room. Evaporation was possible from both top and bottom surfaces, in the conditions of the test.

It is doubtful if a viscid, oxidisable agent like linseed oil, even when diluted with turpentine, is absorbed into the capillary texture of the composition to an extent which makes an effective and permanent seal, but it is evident that its early application to a floor must seriously retard the evaporation, which should be normally unhindered.

This fact is recognised in Continental practice,

where the minimum time allowed after the set, before oiling, is 3 weeks if the floor has been laid under summer conditions, and 6 weeks if laid during the

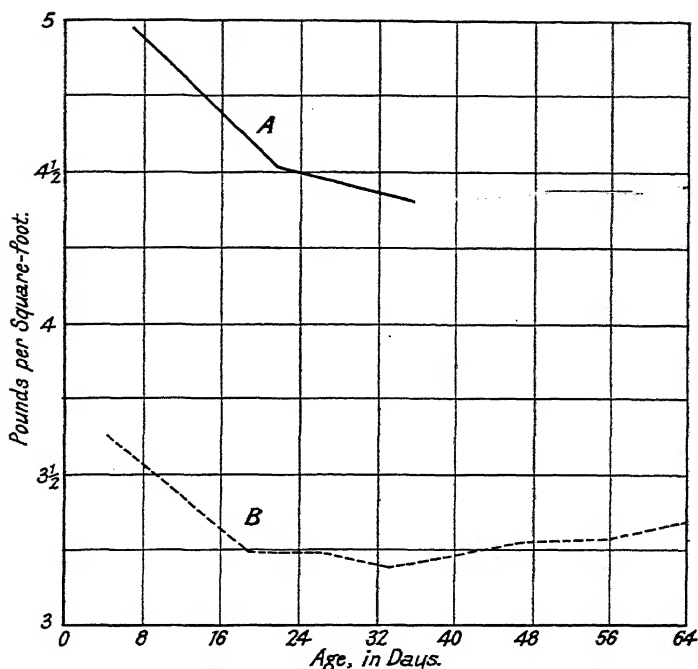


FIG. 14.—Loss in Weight by Evaporation after Set.

(A) Double-layer floor.

(B) Single-layer floor.

winter, with no artificial heat to accelerate drying. The floor is occasionally wiped over with a damp cloth during this period, to remove any magnesium chloride which may collect on the surface.

Although there are no data available, expressly dealing with the point, the practice appears to be a

logical method for preventing much subsequent trouble in the nature of sweating and efflorescence.

There are many difficulties in the way of the floorlayer always following a similar course in this country, where, especially with the smaller jobs, the floor is often expected to be available for use within a day or two of laying. But there is no real objection to the careful use of an unoiled floor for a few weeks. In such case, the customer should be given instructions to wipe over with a wet cloth, at least once a week for, say, a month and then apply several dressings of linseed oil and turpentine at short intervals, wiping over as before between each oiling. After that, the floor may have routine treatment with wax polish, as with linoleum, although it should still have an occasional damping with water.

Floors which are regularly exposed to intensive drying in localised heated areas, as often happens in a factory, should be frequently washed over with water, without flooding, and oiled only at intervals of 2 or 3 weeks.

A dirty floor should never be scoured with soda or washing powder, which will etch the surface, but should be scrubbed with warm water and, if necessary, a little mild soap and then oiled or wax polished. White polish should be used for light-coloured floors.

There are occasional defects in a finished floor, which are demonstrably due to bad materials or poor workmanship.

Patchy and Fading Colour.—Patchiness may be caused by inefficient mixing or by the use of too small a proportion of colour. Some pigments, especially the cheap qualities, are acted upon by magnesium chloride more readily than others, and this causes uneven or general fading and loss of colour value.

When a mix is made extra wet for easy working, there is a tendency for the components to segregate and patchiness will be one of the unsatisfactory results. In single-layer floors there is a greater risk of over-trowelling causing an uneven distribution of the pigment, than in the finishing coat of double-layer floors, where the thinner body of composition requires less working.

Unless pigments are bought under a guarantee, they should be tested, both for any reaction with magnesium chloride and for fastness under strong light.

Green and blue are particularly difficult colours to get evenly effective over large areas. On account of their cost, there is a temptation to cut down the quantity in the mix, but as there is usually a higher price obtained when these colours are specified, nothing but a full proportion of the best-quality pigment is warranted. If pale tints are required, it is better to dilute the colour with a good white pigment before mixing, rather than to reduce the quantity and add direct.

Defective colouring, like some of the other troubles which may beset the floorlayer, cannot be remedied

in the finished floor, but it can be prevented from happening.

Staining from Tools.—Owing to the corrosive action of magnesium chloride on steel, there is a risk of dark streaks being formed on the surface of the floor, as a result of trowelling. This is especially noticeable on light-coloured floors.

Bronze and even glass trowels have been suggested as a remedy, and while the former have distinct advantages, the latter are not likely to be looked upon with favour by the practical man, on account of lack of flexibility. It is doubtful if stainless steel or chromium-plated tools would overcome the difficulty, as these are less resistant to attack by hydrochloric acid and chlorides than to other corrosive agents.

Unless the floorlayer is disposed to have his trowel blades cut from sheet bronze, he must make the best of the ordinary steel tools, and there is no doubt but that the risk of staining can be very much minimised if these are kept clean. An occasional wash with water during use will prevent too prolonged an action by the magnesium chloride, and all tools used on the wet mix should be washed and dried when work is stopped.

Mechanical Defects.—When a floor proves unsatisfactory, the layer generally ascribes the cause to the magnesite. This component is, admittedly, often an uncertain factor in the operation and will continue

to be so, until conformity with the requirements of a straightforward specification is guaranteed by the suppliers.

It is unreasonable, however, to blame the magnesite for all the difficulties which are met. It sometimes happens that a mix behaves in an abnormal manner, when the other components are known to be of the usual standard, the foundation is satisfactory and the layer has done his job properly. In this case, some variation in the properties of the magnesite is probably the reason. But there are other causes of failure, which are within the power of the floorlayer to rectify. At the risk of repetition, some of these may be summarised as follows:—

(1) If the type of sub-floor is not suitable as a base for magnesite composition, the layer should not proceed with the work. Permanently damp conditions have been the explanation of many bad floors. Reinforcement should always be used over a springy wood floor or other non-rigid foundation.

(2) If measures are not taken to prevent absorption of magnesium chloride solution by the sub-floor, the mix will not bond efficiently and cracking, due to shrinkage, will most certainly follow.

(3) Unless the dry materials are thoroughly incorporated, and this can only be done by machine mixing, the floor will be unsatisfactory in appearance and of uneven hardness and strength.

(4) The specific gravity of the magnesium chloride solution, except for the under-layer, which is not exposed to wear, should not be less than ~~1.22~~ ^{1.22} ~~Be~~ ^{Be}

It has already been shown that the oxychloride mix rapidly loses strength as the concentration lessens until, at 14° Be, magnesium chloride solution has no advantage over water alone.

(5) When the mix is too wet, the action of trowelling will form a thin layer of hard material at the surface, giving a sort of case-hardened effect. The substratum never really hardens and when the skin is broken, the floor quickly disintegrates. An unduly plastic mix contains an excess of magnesium chloride solution, which is not an advantage, and a stiffer mix gives much better results. It is probable, too, that this excess of chloride is a frequent cause of later trouble in the form of sweating and efflorescence.

(6) Composition flooring should not be laid while any localised source of heat, such as a radiator or furnace, is working. An abnormally quick set will be induced and the floor will be hard before volume stability is reached, with cracking or buckling as a result.

Expansion and Contraction.—Theoretically, any change in the volume of the flooring material should take place while it is still sufficiently plastic to absorb the effect of movement and factors for expansion and contraction should be mutually corrective. In practice, this does not happen in quite such a satisfactory way and the object of the floorlayer is to reduce these actions to a minimum. Expansion will cause a floor to buckle or part from its base and contraction leads to the formation of cracks.

When a composition floor is going through the setting stage and for some time afterwards, there is considerable loss of water by evaporation, which decreases the mass and causes shrinkage. With the progress of the oxychloride reaction, there is an alteration in structure and a tendency towards expansion, which is largely dependent upon what may be termed the activity of the calcined magnesite.

External agencies which accelerate evaporation, such as high temperature and low atmospheric humidity, are contributory causes of contraction. Such a filler as asbestos may increase the capillarity of the composition and so favour evaporation. If the mix is too wet, it naturally has more water to lose and mass shrinkage due to evaporation is relatively greater.

In a broad sense, contraction is governed by physical and expansion by chemical considerations, and it is chiefly in the latter connection that the quality of the magnesite has a determining effect on the ultimate condition of the floor.

It should be apparent that, apart from mechanical failure of the sub-floor, it is within the power of the floorlayer largely to control the factors which cause shrinkage and so reduce the danger of cracking to a minimum.

Expansion is rarely serious enough to be a source of trouble, but if it does occur, the origin can be generally attributed to the magnesite. If there is any reason for apprehension in this respect, the proportion of magnesite in the mix should be reduced,

but the only real safeguard is a quality guarantee from the suppliers.

It should be remembered that any natural tendency of the composition to expand or contract, is largely counteracted by effective bonding to a sound base. If the underlying concrete carries a screed coat, which is not completely adherent, this resistance to movement will not operate and a floor, which in other circumstances might be permanently satisfactory, will develop shrinkage cracks, or more probably, will "blow" or part from its base.

Sweating.—This should not be confused with condensation. The latter is a deposition of moisture from a humid atmosphere, on a surface which is relatively colder than the air, as happens on a window-pane or a mirror. Sweating is an exudation and has no direct external origin. On account of the low heat conductivity of a composition floor, true condensation does not often happen under ordinary conditions and the liquid film which sometimes forms on the surface will always contain magnesium chloride.

This statement requires some qualification. It is often noticed that sweating is more likely to occur in damp weather, when the atmosphere is heavily charged with moisture. When a plastic mix is worked, either by trowelling a plain floor or by tamping a mottled floor, the surface becomes wetter, on account of magnesium chloride solution being squeezed upwards. This solution carries with it

some of the magnesite and the result is a relatively greater proportion of magnesium oxychloride in the upper part of the floor. The oxychloride compound consists of magnesia, magnesium chloride and water, in unstable association, as a hydrated solid. The magnesium chloride can still take up more water, and if this is available in abnormal amount in the atmosphere, a solution will be re-formed and appear as an exudation.

A frequent cause of sweating is the use of too wet a mix and consequent excess of magnesium chloride over the effective requirements for the oxychloride reaction. Also, if the floor is oiled before it has had sufficient time to dry off, after the set, intermittent sweating may take place, with persistence over a very long period.

Reference is made in the next section to the action of calcium chloride in inducing efflorescence, and it is interesting to note here that it is usually a constituent of the solution exuded when sweating takes place.

The best preventive is regular washing of the floor during the first few weeks, before any oiling or waxing is done. Any later exudation should be washed off with one or two changes of water, not merely wiped off. If left, it may disappear, not by drying but by reabsorption into the floor and this should be prevented.

The phenomenon of sweating and the apparently irrational manner in which it occurs, as, for example, its rarity on a floor laid over wood, is open to various scientific interpretations, but until these are brought

more closely into line with the practical work of the floorlayer, they will not be of much service. So far as present knowledge goes, the chief causes of the trouble are those already mentioned.

Efflorescence.—Although efflorescence is usually associated with sweating, it may take several forms, which arise from quite different causes. It is commonly supposed to consist of magnesium chloride which has been deposited by evaporation of the exuded solution. This is not the case. Magnesium chloride is of a very deliquescent nature, readily absorbing water from the air, so that in the ordinary sense the solution cannot dry up.

If the solid chloride contains several units per cent. of alkaline salts, efflorescence often appears over the finished floor. These salts do not function in the oxychloride reaction but remain in a state of solution and find their way to the surface by capillary action. The moisture evaporates and a powdery deposit is left. When efflorescence is evident in the early life of a floor, the magnesium chloride which has been used should be tested for alkaline and other impurities.

An apparent efflorescence may also be the result of atmospheric carbon dioxide acting upon a surface solution of magnesium chloride, with the formation of carbonate. This action is accelerated by the presence of calcium chloride, which may exist as an impurity in the magnesium chloride or may be formed from lime existing in the magnesite. One

case of pronounced efflorescence examined by the writer was due chiefly to the occurrence of calcium chloride and magnesium sulphate in excessive amount in the magnesium chloride used.

The use of mineral oil in addition to, or in substitution of, linseed oil, especially if applied very shortly after the set, appears to have some action inducing early efflorescence.

In addition to a routine quality control of materials the precautionary measures which are advisable for reducing the risk of sweating are also of service in preventing efflorescence.

CHAPTER XV

PROPERTIES OF COMPOSITION FLOORING

General Characteristics.—An oxychloride composition, which has been prepared on technically sound principles and laid by an expert, provides not only one of the most satisfactory and durable floor finishes for practical use but also one of the most pleasing in appearance.

It is free from dusting and splintering and, after the early stages, needs only the attention which should be given to a good linoleum. It can be, if wished, kept with a highly polished surface. On account of its hardness and comparative freedom from absorption, it does not readily become marked with scars and stains.

When necessary, the flooring can be cut like wood and it gives a good holding for screws. The coarse mix, used as an under-layer, provides in itself an excellent foundation for rubber flooring or heavy linoleum.

If the floor is properly treated in the first few weeks, there should be no appreciable volume change later and its resilience will readily take up any contraction or expansion, which may be induced by

changes of temperature, in the concrete or other base to which it is adherent.

Decorative Possibilities. — Magnesite flooring is especially adapted to decorative treatment. With light-coloured wood flour in the aggregate, the unpigmented composition yields a natural ivory or cream tint, which provides a very suitable basis for the attainment of a wide range of colour effects, by the incorporation of mineral pigments. Contrasting results, with inset designs or lettering, borders, lines, etc., may be readily produced to conform with practically any colour scheme.

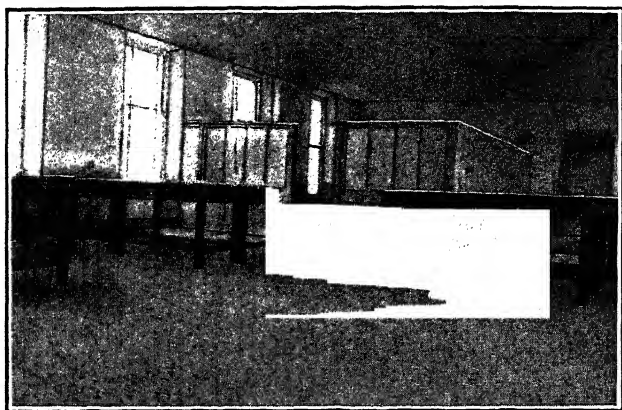
Apart from the quality of the materials in the composition and the craftsmanship necessary to the operation, two considerations are of importance if the applied decoration is to be pleasing in appearance and of permanent value.

(a) Pigments used for decorative treatment should be of the highest grade.

(b) Designs for the reception of insertions in other than the ground colour, should be cut out after the main floor has set. The occasional practice of laying the plastic material up to a lath as a stop, to form a finishing edge where the pattern is to be inserted, is not satisfactory, as a clean line at the junction with the contrasting colour cannot be obtained by this method.

Hygienic Properties.—Apart from the dustless and non-absorbent character of magnesite flooring under

ordinary conditions and the ease with which it can be kept clean, particularly if finished to a cove at the skirting, experiments in the United States have proved that the composition is in itself antiseptic, with a positive germicidal action. It was found to prevent the growth of cultures of the *B. coli* type, with which it had been inoculated.



[Photo: British Magnesite Flooring Co., Ltd.]

FIG. 15.—An Office Floor.

There is a field for further research in this direction, but enough is known fully to justify the advantages of magnesite flooring, in this special respect, for use in hospitals and clinics and for operating theatres.

Resilience.—There is some confusion as to exactly what is meant by the resilience or elasticity of a composition floor.

This describes the property, which it has to a high degree, of recovering after distortion due to

outside agency, such as the temporary bending under load of the sub-floor forming the foundation. It is this property which makes magnesite composition, in double-layer form, so valuable a material for application to old wood flooring, carried on joists, as without it any movement would result in serious cracking.

Mechanical Strength.—The tensile and compressive strengths of composition flooring material are not of primary importance, except so far as they are indications of other desirable properties, although it does not necessarily follow that a floor composition which shows high mechanical strength is on this account, for example, highly resistant to abrasive wear.

There is a rapidly progressive gain in strength during the first 2 or 3 months of the life of a floor. The simplest type of mix, consisting of 2 parts of magnesite and 1 part of sawdust, by weight, will give a tensile strength, in pounds per square inch, of 200–250 at 3 days, 300–350 at 7 days and 550–600 at 56 days.

The table on page 110 gives some results of tests by the Dow Chemical Company on commercial flooring mixes used in the United States. The control mix quoted in comparison, is the standard one mentioned on page 70.

Considered only as a cement and tested with a balanced aggregate of fine silica and sand, magnesium oxychloride will give much higher strength values than Portland cement, comparably examined, but

these strengths are reduced in the ordinary flooring composition by the presence of wood flour or sawdust.

**Tensile and Compressive Strengths and Brinell Hardness
of Composition Flooring**

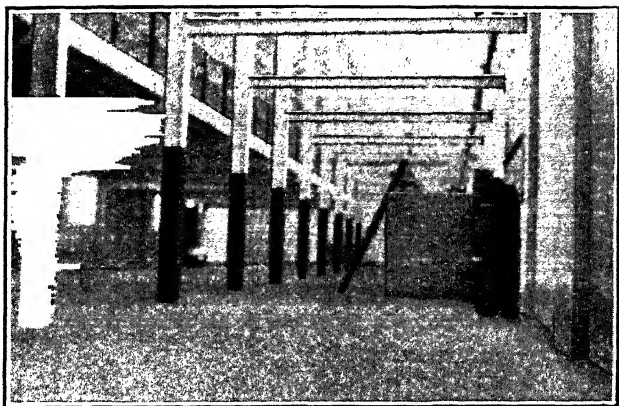
	Control Mix.	Commercial Mixes.	
	lb./sq. in.	A lb./sq. in.	B lb./sq. in.
7-day Tensile . . .	487	420	459
30-day Tensile . . .	659	681	774
7-day Compressive . . .	2871	2423	2627
30-day Compressive . . .	3303	3612	3978
Ratio Compressive to Tensile at 7 days	5.9	5.8	5.7
Ratio Compressive to Tensile at 30 days	5.0	5.3	5.1
7-day Brinell Hardness . . .	6.2	6.9	6.4
30-day Brinell Hardness . . .	7.6	9.5	10.2

Resistance to Abrasive Wear.—High wearing resistance is characteristic of magnesite floors and is perhaps the property which can most readily be modified for special needs. A factory, for example, demands a much harder-wearing floor than would be needed in a living-room.

In a single-layer floor, an increase in hardness is obtained at the cost of some resilience, although, in the special circumstances where this may be called for, the sacrifice is not usually of importance. In a double-layer floor, elasticity is furnished chiefly by the coarse sawdust composition which forms two-thirds of its thickness. By the addition of silica or,

other suitable filler, the finishing coat can be made sufficiently resistant to abrasive wear, to meet any reasonable requirement, while the floor, as a whole, remains resilient enough to counteract any slight movement to which it may be subject.

The Dow Chemical Company have prepared a table which shows the relative immunity from wear of a



[Photo: *British Magnesite Flooring Co., Ltd.*
FIG. 16.—A Factory Floor.

number of types of flooring. The tests were made with an abrading machine designed for the purpose. Comparisons were made with hard maple, which was given a standard figure of 100. Many samples of flooring material were examined, and among these the following results are of interest:—

Semi-hard oxychloride flooring	103
Resilient " " (1st series)	51
" " " (2nd ")	47
Marble	28
Portland cement (1-2)	14

Resistance to Corrosion.—Magnesite composition, although not immune from attack by highly corrosive chemicals, such as mineral acids, has considerable powers of resistance against many agents which often have a disintegrating effect on other types of flooring. It compares very favourably with any floor containing Portland cement, in respect to the action of milk, beer, syrup, petrol, oil, etc., and with the mix modified to meet special conditions, provides an excellent medium for general industrial purposes. Oil, for instance, has a deteriorating effect on cement concrete, while its absorption into the fibrous aggregate of a magnesite floor is not only beneficial to the composition but directly increases its resistance to outside attack.

Resistance to Weather.—The question of behaviour under continuous exposure to changing weather conditions does not often arise in this country, where the use of magnesite flooring is restricted almost entirely to interior work. It is commonly stated that oxychloride compositions are useless for outdoor application, but this is not correct.

In the United States, various forms of magnesite stucco have given satisfactory service, on exterior walls, for many years, under wider extremes of climatic conditions than are usually experienced in Britain. Except for small proportions of short fibre or powdered asbestos, no porous aggregate is used in stucco composition, and consequent absorption of water, causing swelling and possible

disruption, does not take place to any serious extent.

In the course of continual exposure, magnesium chloride, which is in rather an unstable association in the oxychloride complex, is slowly leached out by rain, but the effect is counterbalanced by the entry of atmospheric carbonic acid and the formation of magnesium carbonate, which continues to act as a bond.

Tests in this country, which have lasted over a number of years, indicate that an oxychloride flooring mix, embodying only mineral aggregate, will stand up very well for outdoor use. Attempts have been made to use mineral oils and other organic agents, in the form of an emulsion with magnesium chloride solution, to render magnesite flooring, containing wood aggregate, absolutely waterproof and non-absorbent and so suitable for exterior application. The data are at present insufficient to enable an opinion to be formed on the merits of the claims which are made for the process.

Thermal Conductivity.—Oxychloride flooring and especially the double-layer type, with its substratum of coarse sawdust, has low heat conductivity and therefore remains cool under summer conditions and relatively warm in winter. This characteristic is largely dependent upon the proportion of non-mineral aggregate and the heat-resisting properties can be enhanced by increasing the thickness of the under-layer. This is notably the case when the material

is used for covering the steel decking of ships, where low thermal conductivity is an important consideration and a thickness of several inches of coarse sawdust composition is frequently used.

Fire Resistance.—Magnesite composition, on prolonged exposure to direct flame, disintegrates, owing to the decomposition of the oxychloride binding medium. It does not shatter or fly, but slowly breaks down to a powder. Notwithstanding its normally high content of wood, the material does not smoulder, and although not strictly fireproof, in the sense that it remains unaffected at any temperature, it cannot act as a fire conductor, as, for example, timber does.

Electrical Conductivity.—It is often claimed that a magnesite floor is a non-conductor of electricity. With certain qualifications, this is true of a dry floor. Samples of composition flooring, of several types, pigmented with metallic oxides, were tested across their thickness ($\frac{1}{2}$ inch to $\frac{3}{4}$ inch) with direct current, up to about 500 volts, and all showed zero conductivity. None of these samples was less than 2 years old.

Some specimens which had been prepared 6 weeks previous to the test were similarly tried with a current at 200 volts. A voltmeter in the circuit registered an initial drop in pressure to 50 volts with the single-layer and to 45 volts with the double-layer samples. This fell to zero in a few seconds, in each case.

The samples under test had reached the stage of practically constant weight, following the normal early loss by evaporation, so that temporary conductivity was not due to wetness, in the ordinary sense. There appears to be a phase in the early life of the composition, when a proportion of the magnesium chloride is still chemically free and, to some extent, mechanically separable. In this state it can be electrolysed and will permit current to pass, but immediate polarisation takes place with an interrupting effect. There can be no conductivity, due to electrolytic action, with alternating current.

Weight of Composition Flooring.—Although not an important item in the structural load, inquiry is sometimes made concerning the weight of a composition floor. A normal mix, after setting, loses about 15 per cent. of its weight, by evaporation, during the first month, at first rapidly and then more slowly. Afterwards there is a slight recovery.

Floors laid by different firms vary in weight within narrow limits, but an average value may be taken as 30 lb. for single-layer and 40 lb. for double-layer floors, per square yard, when about 2 months old.

CHAPTER XVI

THE POSITION OF THE COMPOSITION FLOORING INDUSTRY

COMPOSITION floorlaying requires a high standard of technological knowledge and experience. The selection of components, together with the grading and adjustment of mixes to meet varying conditions, should be a task for the expert. Operators need long training to qualify them for the specialised work involved in laying and finishing a magnesite floor.

Magnesium oxychloride cement, together with the various forms of aggregate used with it, is quite unlike any other plastic medium in its behaviour. Its handling calls for the skill of a craftsman, who must, when occasion demands, be competent to act upon his own initiative. There is, to a limited extent, a business in the sale of ready-made flooring mixes and magnesium chloride to purchasers who may have no experience whatever of the properties of the material. It will be obvious that the practice is most undesirable and, so far as it goes, can do no good service to the reputation of magnesite flooring.

It has been said, in connection with metallurgical operations, that a capable foreman can estimate more closely the temperature of a furnace, by inspection

alone, than a scientific observer can do with a pyrometer. This is not quite an accurate statement, for what he is judging is a general suitability of conditions for the work which is being done, irrespective of one important factor being represented by a figure.

In his different sphere, a similar claim is sometimes made for the experienced floorlayer, who may also show an intelligent application of rule-of-thumb principles, but there is really no parallel. The furnace foreman is working under conditions which are wholly controllable. He knows exactly what he is handling and his efforts are directed towards securing the best results, by minor manipulations of a process which has been devised upon a scientific basis.

The British floorlayer does not yet work with a chemist and a physicist in the background and his knowledge has been gained empirically. He may modify his methods to meet unexpected conditions, but often this has to be done experimentally and perhaps doubtfully, because of an incomplete appreciation of the operation and effect of the factors which govern his work.

Our older-established floorlaying firms have gained, in the course of years, a great deal of experience of their medium, and many satisfactory floors all over the country offer evidence of this. It must however be conceded, that with one or two exceptions, magnesite floorlaying operations in Great Britain still lack the safeguard of close scientific control. The technology is not yet free from uncertainty, and failures,

which the floorlayer cannot explain, still sometimes occur.

There has been nothing yet done in this country comparable with the valuable systematic researches of the Dow Chemical Company in the United States or with the centralisation of technical investigation at the Steinhilzverband in Germany. The results of these activities are available, to a limited extent, for British workers, but because of certain differences in practical application, the problems which have been studied are not always exactly the same as those which confront our own floorlayers.

From time to time, experimental work on materials has been conducted at the Building Research Station, to the considerable advantage of the flooring trade, but these investigations have not been extended on the scale which is warranted by their importance, presumably because of other demands upon the resources of the Station.

The experience gained by the reputable floorlaying firms has been put to good service, but composition floors are still, in some quarters, looked upon with disfavour. There is certainly some reason for this attitude, which has inevitably followed from the entry into the industry of a number of small concerns with very little qualification or material equipment for the work.

Such comparisons as are made here are not intended to be read as an argument for the big undertaking, purely as such. But there are minimum requirements, both financial and technical, which

are essential and, far more often than not, the type of firm to which exception is taken cannot fulfil them.

Very few firms operate on a large enough scale to buy their magnesite for delivery in 50- or 100-ton lots, but regular purchasers should be in a position to stipulate reasonable quality needs to the merchant. The man who buys a few bags at infrequent intervals cannot insist upon a standard product, even if he knows what he ought to have. The advantages of systematic as against haphazard buying are equally pronounced with the other components which are used.

Responsible firms pay fair prices for their materials. They pay standard wages to their operatives and are prepared for overtime rates when a floor needs attention outside the normal hours of work. They give special attention to the foundation upon which a floor is to be laid and, if it is unsuitable, they will not undertake the job. In the event of dissatisfaction, they will stand by their guarantee.

When labour costs are cut to a minimum and cheap materials are used, it is possible to supply a floor at a low price but of very poor quality. A false standard of value has grown up accordingly. Architects should realise that a good composition floor is well worth paying for and will be cheaper than any alternative which has a claim to corresponding merits.

Representative members of the flooring trade have now taken united action and, with the co-

operation of the Building Research Station, have been engaged in framing recommendations for guidance in laying magnesium oxychloride floors. These, when made available, should be of great assistance, not only to the practical floorlayer but also to the architect.

The latter will be informed of the various types of sub-floor which furnish suitable foundations for a composition overlay and of the conditions which the floorlayer has a right to expect, in order to enable him to do his work in a satisfactory manner. The architect, for the first time, will be in a position to specify that materials and workmanship shall conform with a recognised standard and he will be able, if he wishes, to verify this during the progress of the work. The "Jointless Flooring (Oxychloride) Association" has been formed by the floorlaying firms and membership implies an acceptance of the official recommendations and specifications and an undertaking to work in accordance with them.

These activities should lead to a more uniform standard of practice and a generally higher level of quality in output, but until the trade is in a position to command regular facilities for technical service and organised research, the full benefit of co-operation will not be attained.

Until this is done and there is some centralised authority, acting for the whole of the trade, to which flooring problems may be referred, it may occasionally be advisable for the architect to avail himself of independent advice. It may happen that the

installation of a composition floor is desirable for many reasons, but there is some doubt about its suitability in one particular respect. A typical example is when the floor is proposed for a factory and the effect upon it of some active agent or abnormal condition to which it may be exposed is unknown. If the floorlayer is unable to give the required assurance, from his own experience, then it would be wise to seek expert assistance. A modification in the composition of the mix or in the method of application or treatment may overcome the difficulty and avoid later inconvenience and expense.

APPENDIX

COMPARISON OF HYDROMETER SCALES

Baumé degrees.	Twaddell degrees.	Specific Gravity.	Baumé degrees.	Twaddell degrees.	Specific Gravity.
0	0	1.000	19.0	30.4	1.152
1.0	1.4	1.007	20.0	32.4	1.162
2.0	2.8	1.014	21.0	34.2	1.171
3.0	4.4	1.022	22.0	36.0	1.180
4.0	5.8	1.029	23.0	38.0	1.190
5.0	7.4	1.037	24.0	40.0	1.200
6.0	9.0	1.045	25.0	42.0	1.210
7.0	10.2	1.052	26.0	44.0	1.220
8.0	12.0	1.060	27.0	46.2	1.231
9.0	13.4	1.067	28.0	48.2	1.241
10.0	15.0	1.075	29.0	50.4	1.252
11.0	16.6	1.083	30.0	52.6	1.263
12.0	18.2	1.091	31.0	54.8	1.274
13.0	20.0	1.100	32.0	57.0	1.285
14.0	21.6	1.108	33.0	59.4	1.297
15.0	23.2	1.116	34.0	61.6	1.308
16.0	25.0	1.125	35.0	64.0	1.320
17.0	26.8	1.134	36.0	66.4	1.332
18.0	28.4	1.142	37.0	69.0	1.345

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The formation of the Association is the result of discussions in 1934 and 1935 at conferences of members of the industry convened at the suggestion of the Building Research Station, when consideration was given to the best methods of ensuring, in the interest of the trade as a whole, the maintenance of sound practice in the laying of oxychloride floors. It was agreed that an essential step in that direction was the formation of an Association to encourage sound practice, provide for research on a joint basis and develop a public appreciation of the merits of the oxychloride floor. It is a condition of membership that members undertake to comply with the standards adopted by the Association.

The Association was formally constituted in November 1935. Meantime, there had been at work in collaboration with the Building Research Station, a committee appointed by the conference, which had formulated in outline:—

- (1) Recommendations for the manufacture of Magnesite composition flooring and dados.
- (2) Suggested basis of specifications for the materials used in the manufacture of Magnesite compositions.

The Building Research Board has undertaken to assume responsibility for publishing the "Recommendations" and has set up a committee to review and complete the document for publication. The British Standards Institution has been invited, through the Building Research Station, to arrange for the completion and issue of the "Specifications."

These documents, when published, will, it is intended, become the standards of practice adopted by the Association.

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